ISSN 2313–5891 (Online)
ISSN 2304–974X (Print)

Ukrainian Food Journal

Volume 11, Issue 4
2022

Kyiv **Київ**

2022

Ukrainian Food Journal is an international scientific journal that publishes articles of the specialists in the fields of food science, engineering and technology, chemistry, economics and management.

Ukrainian Food Journal – міжнародне наукове періодичне видання для публікації результатів досліджень фахівців у галузі харчової науки, техніки та технології, хімії, економіки і управління.

Ukrainian Food Journal is abstracted and indexed by scientometric databases:

Ukrainian Food Journal індексується наукометричними базами:

Index Copernicus (2012)
EBSCO (2013)
Google Scholar (2013)
UlrichsWeb (2013)
CABI full text (2014)
Online Library of University of Southern Denmark (2014)
Directory of Open Access scholarly Resources (ROAD) (2014)
European Reference Index for the Humanities and the Social Sciences (ERIH PLUS) (2014)
Directory of Open Access Journals (DOAJ) (2015)
InfoBase Index (2015)
Chemical Abstracts Service Source Index (CASSI) (2016)
FSTA (Food Science and Technology Abstracts) (2018)
Web of Science (Emerging Sourses Citaton Index) (2018)
Scopus (2022)

Ukrainian Food Journal включено у перелік наукових фахових видань України з технічних наук, категорія А (Наказ Міністерства освіти і науки України № 358 від 15.03.2019)

Editorial office address:

National University
of Food Technologies
68 Volodymyrska str.
Kyiv 01601, **Ukraine**

Адреса редакції:

Національний університет
харчових технологій
вул. Володимирська, 68
Київ 01601, **Україна**

e-mail: **ufj_nuft@meta.ua**

Scientific Council of the National University of Food Technologies approved this issue for publication. Protocol № 7, 28.02.2023

Рекомендовано вченою радою Національного університету харчових технологій. Протокол № 7 від 28.02.2023

Ukrainian Food Journal is open access journal published by the National University of Food Technologies (Kyiv, Ukraine). The Journal publishes original research articles, short communications, review papers, news and literature reviews dealing with all aspects of the food science, technology, engeneering, nutrition, food chemistry, economics and management.

Studies must be novel, have a clear connection to food science, and be of general interest to the international scientific community.

Topic covered by the journal include:

– Food engineering
– Food chemistry
– Food microbiology
– Food quality and safety
– Food processes
– Automation of food processes
– Food packaging
– Economics
– Food nanotechnologies
– Economics and management

Please note that the Journal does not consider:

1. The articles with medical statements (this topic is not covered by the journal); the subject of research on humans and animals.
2. The articles with statements, that do not contain scientific value (solving the typical practical and engineering tasks).

Periodicity of the Journal

4 issues per year (March, June, September, December).

Reviewing a Manuscript for Publication

The editor in chief reviews the correspondence of the content of a newly submitted article to the Journal Profile, approves the article design, style and illustrative material, can provide suggestions how to improve them, and makes the decision whether to send it for peer-review.

Articles submitted for publication in "Ukrainian Food Journal" are double-blind peer-reviewed by at least two academics appointed by the Editors' Board: one from the Editorial Board and one, not affiliated to the Board and/or the Publisher.

For a **Complete Guide for Authors** please visit our website:

http://ufj.nuft.edu.ua

Contents

Technological functions of hydrolyzed whey concentrate in ice cream

Oleksandr Shevchenko[1], Artur Mykhalevych[1], Galina Polischuk[1], Magdalena Buniowska-Olejnik[2], Oksana Bass[1], Uliana Bandura[1]

1 – National University of Food Technologies, Kyiv, Ukraine
2 – University of Rzeszow, Rzeszow, Poland

Keywords:

Ice cream
Whey
Lactose
Hydrolysis
Sweetness
Thixotropy

Article history:

Received 17.06.2022
Received in revised form 21.11.2022
Accepted 30.12.2022

Corresponding author:

Oksana Bass
E-mail: kleona@meta.ua

DOI: 10.24263/2304-974X-2022-11-4-3

Abstract

Introduction. The article examines the quality indicators of low-fat ice cream with a different ratio between sugar and hydrolyzed and non-hydrolyzed concentrates of demineralized whey.

Materials and methods. The degree of lactose hydrolysis was determined by iodometric and refractometric methods, the water activity in the mixtures was determined using the water activity analyzer, the rheological characteristics were determined using a rotary viscometer, the foam overrun and foam stability of the ice cream mixtures and the melting rate of ice cream were determined using modified methods, sensory indicators were determined using the descriptive-integral method. The mass fraction of protein, dry matter, overrun, resistance to melting in ice cream were determined using well-known methods.

Results and discussion. Based on the calculation of the degree of sweetness of whey concentrates, taking into account the mass fraction of total solids, the degree of lactose hydrolysis and the known values of the relative sweetness of sugar, lactose, glucose and galactose, a concentrate with a solids content 40% was chosen for use in the ice cream formulation. According to the results of the study of the quality indicators of ice cream mixtures, it was found that the hydrolyzed concentrate of demineralized whey with a mass fraction of solids 40% could replace up to 42% of sugar in the composition of ice cream, while maintaining the degree of sweetness determined for this type of ice cream in the range from 0.8 to 0.9. According to the viscosity-speed characteristics, the mixture of low-fat ice cream with a concentrate of hydrolyzed demineralized whey is classified as a system with a pronounced coagulation structure with the detection of thixotropic properties. Ice cream based on hydrolyzed whey concentrate contains 3.3% of whey proteins, which corresponds to the standard chemical composition of ice cream. The high content of lactose hydrolysis products in ice cream increases overrun, but reduces the resistance to melting of ice cream, which must be taken into account during the technological process and when choosing a consumer container.

Conclusions. The feasibility of using a hydrolyzed whey concentrate with a mass fraction of solids 40% as a sweetening and protein-containing ingredient in low-fat ice cream has been proven.

Introduction

One of the modern trends in the food industry is the production of low-calorie dessert products, including ice cream. The calorie content of ice cream is usually reduced by limiting its fat content (not higher than 5%), but its absence or low content leads to the formation of a coarse crystalline structure, a dense consistency and a decrease in the melting resistance of this product (Bass et al., 2018; Özdemir et al., 2018; Syed et al., 2018). The quality of low-fat ice cream is usually improved by using in its composition technologically effective food hydrocolloids, in particular polysaccharides and products of their chemical modification or destruction (Aljewicz et al., 2020; Goff et al., 2019). Polysaccharides actively bind water, structure mixtures, stabilize dispersed ice cream systems, but practically do not affect the nutritional value of the product. Instead, proteins, including milk proteins, as natural biopolymers perform not only technological functions in the composition of ice cream, but also additionally enrich it (Akalin et al., 2008; Polishchuk et al., 2020). Recently, in the composition of dessert products, protein-containing whey processing products are increasingly used, in particular, fermented whey as a source of proteins and carbohydrates. In whey concentrates with hydrolyzed lactose, the number of molecules dissolved in the aqueous phase increases by 1.5–1.8 times, compared to concentrates before hydrolysis, which significantly affects their sensory properties, osmotic pressure and cryoscopic temperature. Enzymatic hydrolysis of lactose also increases the sweetness of whey concentrates, which can be used as sweetening ingredients (Majore and Ciproviča, 2020). Therefore, the scientific justification of the partial replacement of sugar with hydrolyzed whey and the study of the effect of such replacement in the composition of ice cream on its physical and chemical characteristics is an actual applied research.

Ice cream of various types contains not only fresh milk and cream, but also protein-containing ingredients, protein concentrates and isolates. At the same time, milk powder and condensed milk, whey and buttermilk powder significantly increase the lactose content in ice cream. Under these conditions, excessive crystallization of lactose, which has a low solubility, becomes the reason for the appearance of a sandy consistency in ice cream during its low-temperature storage (Alvarez et al., 2005). Therefore, in order to improve the quality of ice cream by reducing the lactose content, additional binding of free water, forming and stabilizing the structure and increasing its biological value, it is more appropriate to use protein isolates and low-lactose protein concentrates (Ganga et al., 2017; Nasser et al., 2018; Polishchuk et al., 2020).

Proteins of different fractional composition, degree of purification and origin show specific technological activity in the composition of ice cream (Nastaj et al., 2019; Peng et al., 2009). Among the proteins of animal and plant origin, the ability of whey proteins to mask the absence or lack of fat and increase the overrun of ice cream (El-Zeini Hoda et al., 2016) deserves special attention, which makes it possible to ensure its high quality while reducing the calorie content and increasing the biological value of the product. However, existing methods of extracting and concentrating whey proteins are quite expensive, which is reflected in their price (Arsić et al., 2019). The cheapest source of whey proteins in ice cream is condensed and powdered whey, but it contains up to 70–75% of lactose from the total solids, which is a limiting factor during its use (Livney et al., 2007). Therefore, the enzymatic hydrolysis of lactose in whey concentrates is advisable, which not only prevents the occurrence of consistency defects during the storage of hardened ice cream, but also increases its degree of sweetness (Chauhan et al., 2010; Trubnikova et al., 2018). Partial hydrolysis of lactose can also be achieved by fermentation of ice cream mixes with lactic acid bacteria (Schmidt et al., 2016).

In ice cream technology, hydrolyzed whey is not only used, but also appropriate hydrolysis of lactose is carried out in mixtures for the production of ice cream. Thus, the hydrolysis of 75% of lactose in ice cream mixes has a positive effect on the physicochemical parameters of the product and allows reducing the sugar content to 25% (Abbasi et al., 2015). Tsuchiya et al. (2017) also proved the feasibility of reducing the sugar content from 20 to 14% due to the use of hydrolyzed whey. Monosaccharides as lactose hydrolysis products lower the cryoscopic temperature, increase the degree of sweetness, form a softer ice cream texture, and facilitate the extrusion process (Wilson et al., 2003). At the same time, reducing the sugar content in ice cream reduces the total amount of solids in the product, which must be taken into account to prevent consistency defects (McCain et al., 2018).

The authors of this article proved that in order to achieve the maximum effect during lactose hydrolysis, it is more effective to use enzyme and starter preparations simultaneously. This method of enzymolysis of demineralized whey concentrates with a solids content 10–40% and a degree of demineralization 70% makes it possible to achieve 80–90% hydrolysis of lactose (Osmak et al., 2021). Hydrolyzed whey concentrate with an increased content of whey proteins and monosaccharides can be a promising ingredient in ice cream technology, which requires additional investigating and outlines the scientific interest of this study.

The aim of research was to determine the functions of hydrolyzed whey concentrate in low-fat ice cream.

To achieve the goal, the following tasks were chosen:

- to determine the possibility of partial replacement of sugar in the composition of ice cream with hydrolyzed whey concentrate containing 40% of total solids;
- to study the physicochemical characteristics of the ice cream mixture with hydrolyzed whey concentrate;
- to study the effect of hydrolyzed whey concentrate on ice cream quality indicators.

Materials and methods

Raw material for research

Hydrolyzed whey concentrate (solids 40%) was selected for use in the composition of ice cream, which was obtained by reconstitution of demineralized dry whey in drinking water (ash – not more than 2.5%, lactose – not less than 79%, protein – not less than 10.7% in conversion to solids).

The liquid preparation β-D-galactosidase-hydrolase with the commercial name GODO-YNL2 ("Danisko", Denmark) was used for the hydrolysis of whey concentrates, which is a producer of breeding strains of *Kluyveromyces lactis*. Under standard conditions of milk hydrolysis for 24 hours at a temperature of (4.4–7.2) °C, the recommended amount of the preparation GODO-YNL2 containing 10% β-galactosidase is 100 g per 100 liters of milk.

For the fermentation of whey concentrates, a fermenting single-strain lyophilized starter *"L. acidophilus LYO 50 DCU-S"* (Danisko, Denmark) was used at the recommended dose of 5 g per 100 liters of milk.

To stabilize the structure of low-fat ice cream, the stabilization system Cremodan SE 406 (DuPont™ Danisco®) was chosen in the amount of 0.6%, in accordance with the manufacturer's recommendations.

Production of whey concentrates and ice cream samples

Dry demineralized whey was reconstituted in drinking water at a temperature of (40–45) °C to obtain a concentrate with a mass fraction of total solids 40%. The concentrate was filtered, pasteurized at a temperature of (85–88) °C for 3–5 minutes, cooled to a temperature of (40–43) °C and fermented with the preparation GODO-YNL2 and starter based on "*L. acidophilus LYO 50 DCU-S*". In case of simultaneous application of GODO-YNL2 and a starter during the lag phase of *L. Acidophilus* development (2–4 hours), the enzyme manages to detect hydrolytic activity at an active acidity of pH ≥ 5.7, and, as a result, lactose hydrolysis reached 80–90%.

Mixtures with non-hydrolyzed whey concentrate (5 control samples) and mixtures with hydrolyzed whey concentrate (5 experimental samples) were prepared with a simultaneous decrease in the sugar content from 17 to 9% and an increase in the content of 40% whey concentrate in the amount from 0 to 30% by mass fraction of total solids.

The mixtures were filtered, pasteurized at a temperature of (85±2) °C for 5 minutes and homogenized at a pressure of (12.0±2.5) MPa using a laboratory homogenizer-disperser model 15M-8TA "Lab Homogenizer and Sub-Micron Disperser" (GAULIN CORPORATION, Massachusetts, USA). The homogenized mixtures were cooled to a temperature of (4±2) °C, kept for at least 2 hours and frozen using a periodic freezer of the FPM-3.5/380-50 "Elbrus-400" brand (Ukraine). The freezing process was carried out in 2 stages:

1. The stage of cooling to a temperature of minus 2 °C at a stirrer speed of 270 rpm;
2. The stage of freezing to a temperature of minus 4 °C at a stirrer speed of 540 rpm. The samples of soft ice cream were hardened and stored for at least 48 hours in a "Caravell A/S" freezer (Denmark) at a temperature of minus (22±1) °C.

Research methods

Degree of sweetness of whey concentrates was calculated depending on the mass fraction of total solids and the degree of lactose hydrolysis in these concentrates. The authors previously established that the simultaneous use of enzyme and starter preparations makes it possible to achieve a degree of lactose hydrolysis of 80-90%, therefore, the relative sweetness of concentrates was calculated for this range. The range from 0.8 to 0.9 was chosen as the acceptable degree of ice cream sweetness. (Osmak et al., 2021).

The relative sweetness of the non-hydrolyzed concentrate and concentrates with a degree of lactose hydrolysis of 80, 85, and 90% was calculated based on their chemical composition (content of monosaccharides and disaccharides), taking into account the known values of the relative sweetness of sugar (1), lactose (0.16), glucose (0.73), and galactose (0.32).

Lactose content in whey concentrates and test samples of ice cream mixtures was determined by iodometric and refractometric methods (Romanchuk et al., 2018). The refractive index of transparent lactose solutions was determined refractometrically after precipitation of milk proteins with a calcium chloride solution. For complete separation of proteins, lactose solutions were previously centrifuged. The fraction of the refractive index due to the presence of residual mineral salts was conventionally taken as a constant value, and the fraction of the refractive index due to the presence of lactose as a variable value. The accuracy of the determination was calibrated using the iodometric method.

The degree of lactose hydrolysis was taken as the ratio of lactose content in hydrolyzed samples to its initial content, expressed as a percentage (Osmak et al., 2021).

Definition of foam overrun. Experimental ice cream mixes, after cooling to a temperature of (2–6) °C, were whipped using a mixer with a special nozzle for 5, 10 and 15 minutes with breaks of 5 minutes according to the method of Lim et al. (2008a). Foam overrun was determined as the ratio of the volume of the whipped mixture to its initial volume, expressed as a percentage. A foam overrun value of at least 200% was considered satisfactory.

The foam stability of experimental samples of ice cream mixtures was determined according to the modified method of Philips L., according to which a container with a hole at the bottom was used for the foam to flow after whipping (Lim et al., 2008b). The foam stability indicator was taken as the time during which 50% of the initial volume of the mixture, which was used for whipping, is formed as a result of foam destruction.

The viscosity characteristics of ice cream mixtures with non-hydrolyzed and hydrolyzed whey concentrates (mass fraction of total solids – 40%) were determined on a rotary viscometer with a "cylinder-cylinder" measuring system by taking deformation kinetics curves. Measurements were made at a temperature of 20°C. Shear stress τ (Pa) was measured at twelve values of the shear rate gradient (γ) in the range from 3 to 1312.2 s^{-1} during forward and reverse motion. The maximum effective viscosity of the practically undamaged structure (γ = 3 s^{-1}), the minimum effective viscosity of the marginally destroyed structure (γ = 1312.2 s^{-1}) and the effective viscosity of the restored structure (γ = 3 s^{-1}) were recorded. The degree of restoration of the structure of ice cream mixtures (thixotropic ability) was determined as a percentage by the difference in the values of the effective viscosity of the practically intact structure at the beginning and at the end of the measurement at a shear rate gradient (γ = 3 s^{-1}) (Mykhalevych et al., 2022).

Determination of the mass fraction of total solids in ice cream samples was carried out by the arbitration method, the principle of which consists in drying the sample, diluted with distilled water and mixed with sand, at a temperature of 102°C to a constant mass, followed by weighing to determine the mass of the residue.

Determination of the mass fraction of protein in ice cream was carried out by the Kjeldahl method.

The water activity in ice cream mixes was determined on a water activity analyzer "HygroLab 2" (Rotronic, Switzerland) at a temperature of 20°C in the measurement range of 0–1 Aw (0–100% rh) (Kuzmyk et al., 2021).

The overrun of ice cream was determined by the weight method based on the difference in the weight of samples of the same volume of mixture and ice cream, expressed as a percentage (Sofjan and Hartel, 2004). Satisfactory was considered a value of at least 80%.

The resistance to melting was determined by the accumulation time of 10 cm^3 of liquid (melt) flowing out of a sample of ice cream, which was cut in the form of a cylinder with a diameter of 30 mm and a height of 50 mm from ice cream that had an initial temperature of minus 15°C and this sample was placed in a chamber with an adjustable temperature at (20±1)°C. Values not less than 41 min were considered satisfactory resistance to melting.

The melting rate was determined according to the method of Goff and Hartel (2003). Ice cream samples were stored at minus (22±1) °C, selected and placed on a special grid for melting at room temperature (19±1) °C. The weight of the melted ice cream was recorded after one hour every 10 minutes for 2 hours. The melting rate (M, %) was calculated according to the formula:

M = (mass of melted ice cream) / (mass of ice cream until melting) × 100

Sensory evaluation of ice cream with whey concentrates. To conduct a sensory assessment of two samples of ice cream containing non-hydrolyzed or hydrolyzed whey concentrates at the level of 75% and sugar at the level of 11 and 9%, respectively, a descriptive method of sensory analysis was used (Cherevychna et al., 2019), which was modified by the authors of the article. The arithmetic mean of individual indicators was calculated according to the formula:

$$\bar{X} = \sqrt{\frac{\sum_{i=1}^{n} x_i^2}{n}} ,$$

where $\sum_{i=1}^{n} x_i^2$ is the sum of experts' evaluations according to each of the five criteria (taste and aftertaste, smell, appearance, consistency, color) of one ice cream sample;

n is the number of experts.

The standard deviation for each unit indicator was determined by the formula:

$$S = \sqrt{\frac{\sum_{i=1}^{n} x_i^2}{n} - \overline{x^2}} ,$$

where $\sum_{i=1}^{n} x_i^2$ is the sum of squares of experts' assessments, points;

$\overline{x^2}$ is the square of the average value of the indicator's evaluations, points.

The complex indicator Q was calculated according to the formula:

$$Q = \sum_{i=1}^{n} \bar{x}_i ,$$

where $\bar{x}_i$ is average score of a single quality criterion, points.

The coefficient of coincidence was calculated according to the formula:

$$W = \frac{\sum_{i=1}^{n} (x_{i1} - x_{i2})^2}{n} ,$$

where x_{i1} is value of quality assessments of a series of ice cream samples at the first stage of assessment;

x_{i2} is value of quality assessments of a series of ice cream samples at the second stage of assessment;

n is the number of experts.

The integral assessment was carried out on a 100-point scale, which had the following quality gradation: 0–24 – extremely low, 25–39 – low, 40–54 – below average, 55–69 – average, 70–84 – above average, 85- 95 is high, 96–100 is extremely high.

Each of the five quality criteria was graded according to descriptors specific to this type of ice cream, taking into account the recommendations of the international standard ISO 13299:2016.

Statistical processing. Data were expressed as the mean with standard deviation of triplicate measurements. Statistical analysis was performed using the program Statistika 10. Differences were considered reliable at validity α = 0.95.

Results and discussion

Study of the possibility of replacing sugar with hydrolyzed concentrates of demineralized whey

In order to study the degree of sweetness of hydrolyzed concentrates of demineralized whey with a mass fraction of total solids of 10–40% and with a degree of hydrolysis of 80–90%, their relative sweetness was calculated (Table 1).

Table 1

Degree of sweetness of whey concentrates with different degrees of lactose hydrolysis

Mass fraction of solids in whey concentrate, %	Degree of lactose hydrolysis, %			
	0	80	85	90
10	0.0123	0.0345	0.0359	0.0373
20	0.0246	0.0690	0.0718	0.0745
30	0.0369	0.1035	0.1076	0.1118
40	0.0492	0.1380	0.1435	0.1491

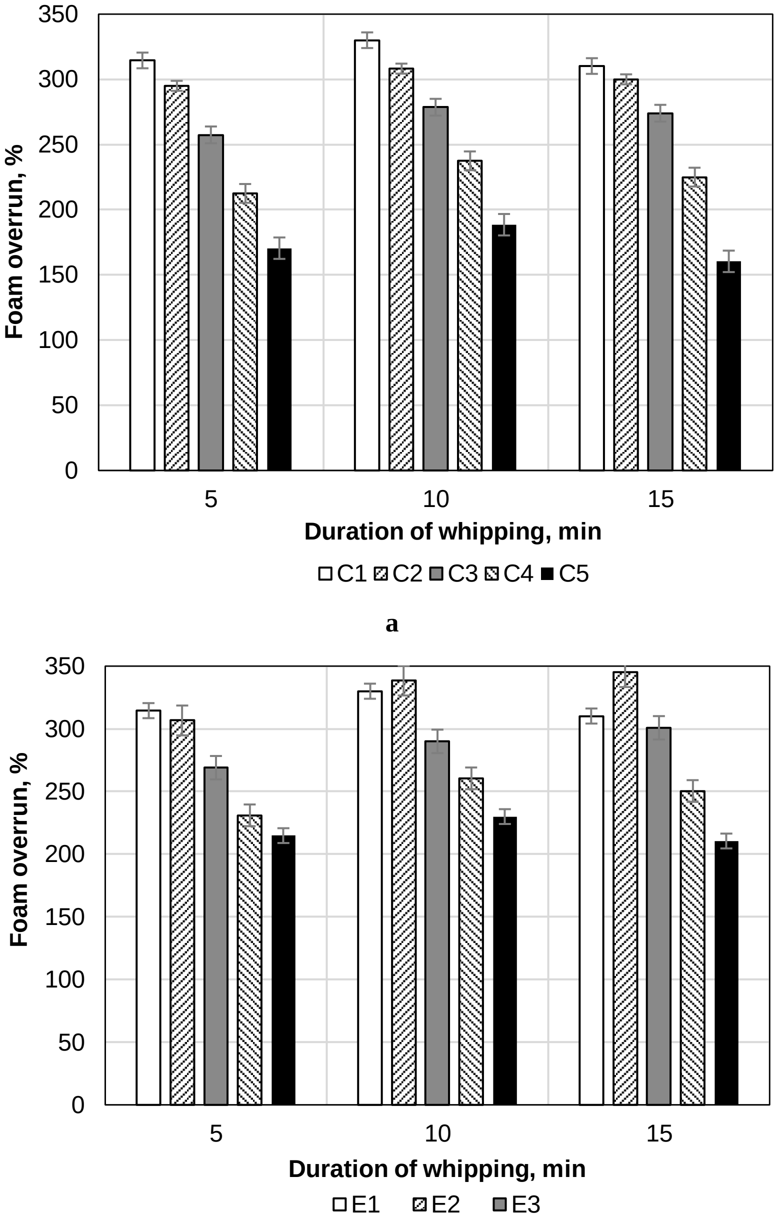
Due to the increase in the content of monosaccharides, as products of lactose enzymolysis, a correlation between the degree of hydrolysis and the degree of sweetness of whey concentrates was noticed (Table 1).

A concentrate with solids content 40% was chosen for further research. This concentrate is the closest in terms of this indicator to the chemical composition of full-fat ice cream and is effective for increasing the solids content of low-fat ice cream to prevent texture defects such as sandiness, coarse crystalline structure, and watery taste (Akalin et al., 2008), because they are caused by an excess of free water. As for the choice of the degree of hydrolysis, within the achieved limits of the efficiency of this process (from 80 to 90%), a slight difference in the degree of sweetness for the hydrolyzed samples is obvious, which will not significantly affect the general recommendations for the development of ice cream formulations with fermented whey concentrates. Therefore, a concentrate with an average degree of lactose hydrolysis (85%) was chosen.

At the next stage, mixtures with non-hydrolyzed whey concentrate (5 control samples) and mixtures with hydrolyzed whey concentrate (5 experimental samples) were prepared with a simultaneous decrease in the sugar content from 17 to 9% and an increase in the content of demineralized whey concentrate in the amount from 0 to 30% mass fraction of solids.

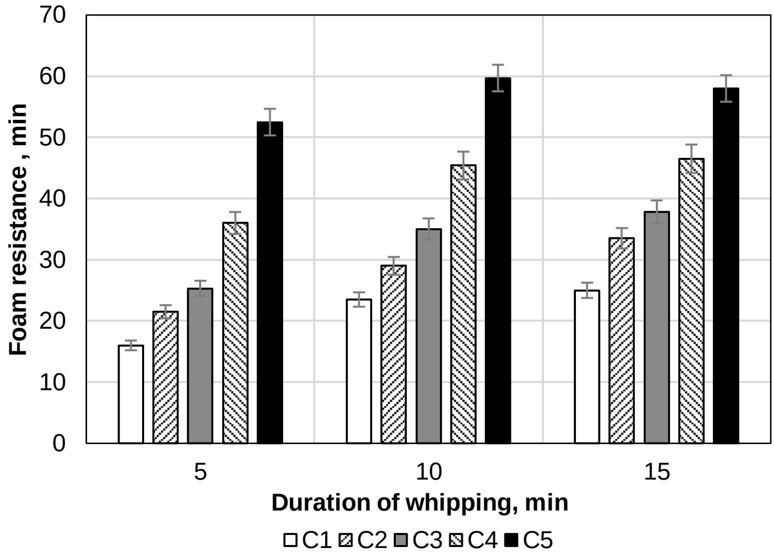
Sucrose in the composition of ice cream plays the functions of a sweetener and a source of solids, ensures the proper formation of the structure of the frozen dessert and affects its physicochemical parameters – overrun and resistance to melting (Atallah et al., 2022; Hinkova et al., 2015). Replacing sucrose with other ingredients, such as monosaccharides, dietary fiber and others, does not always have a positive effect on the quality of the finished product (Ozdemir et al., 2008; Mitchell et al., 2008).

The foam overrun and foam resistance of ice cream mixtures with partial replacement of sugar with whey concentrates were investigated (Figure 1 and 2). The obtained results were to some extent correlated with the data of scientists who studied the quality indicators of ice cream, in particular, whey ice cream (Lim et al., 2008a; 2008b; Pei et al., 2010).

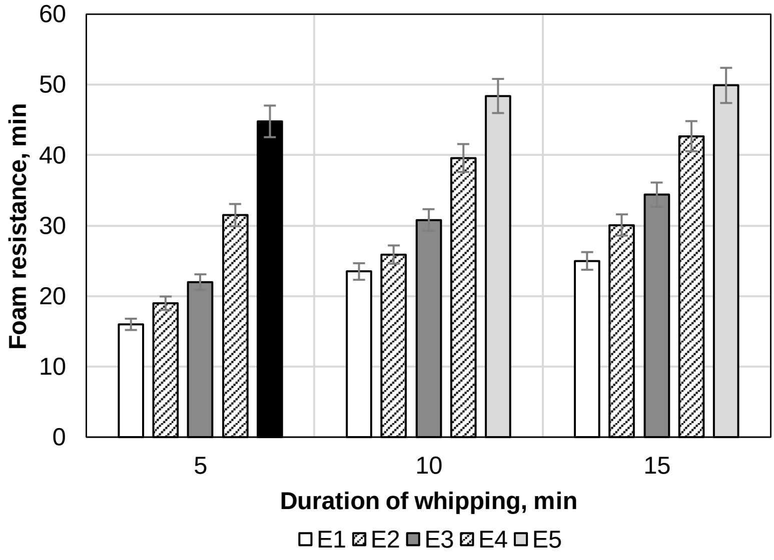


b

Figure 1. Foam overrun of ice cream mixtures with whey concentrates:
a – non-hydrolyzed,
b – hydrolyzed: C1 and E1, 17% sugar, 0% concentrate;
C2 and E2, 15% sugar, 18.75% concentrate;
C3 and E3, 13% sugar, 37.5% concentrate;
C4 and E4, 11% sugar, 56.25% concentrate;
C5 and E5, 9% sugar, 75% concentrate.



a



b

Figure 2. Foam resistance of ice cream mixtures with whey concentrates:
a – non-hydrolyzed,
b – hydrolyzed:
C1 and E1, 17% sugar, 0% concentrate;
C2 and E2, 15% sugar, 18.75% concentrate;
C3 and E3, 13% sugar, 37.5% concentrate;
C4 and E4, 11% sugar, 56.25% concentrate;
C5 and E5, 9% sugar, 75% concentrate.

The foam overrun of mixtures with non-hydrolyzed whey concentrate during the first 10 min increased with a subsequent slight decrease, except for sample C5 with the highest degree of replacement of sucrose with whey concentrate, which caused a sharp decrease in the foam overrun (Figure 1, 2). Samples of ice cream mixtures with hydrolyzed whey concentrate showed increased foam overrun during 15 min of whipping, except for samples E4 and E5, for which foam overrun decreased slightly after 10 min of whipping. Syed et al. (2018) reported that the recommended content of sugar in ice cream is 14–16% within the permissible range of 12–20%. The use of a smaller or larger dose of sugar in ice cream with an increased content of solids can lead to a deterioration in quality indicators. However, the study of ice cream mixtures in this work indicates that using 11% sucrose and 30% solids of non-hydrolyzed concentrate, as well as 9% sucrose and 30% solids of hydrolyzed concentrate, makes it possible to obtain a foam overrun that is higher than the established satisfactory level (200%). Goff (2018) reported about cases of variation in the sucrose content in different types of ice cream, which are in the range of 9–28%, which confirms the impracticality of further reduction of sucrose in ice cream with hydrolyzed whey concentrate. The whey ingredients are also known to increase the foam overrun and foam stability of ice cream mixes. Thus, Lim et al. (2008a) reported that processed whey protein concentrate helps to achieve optimal foam resistance and foam overrun in low-fat ice cream mixes (37.94% of total solids), however, in our study, foam resistance was lower, while foam overrun was higher, which is related with varied content of total solids in samples (from 18 to 41.61%) and adsorptive action of monosaccharides in samples with hydrolyzed whey concentrate, which ensures uniform distribution of free moisture and its retention. İbanoğlu and Karataş (2001) found that high-pressure treatment of whey protein concentrates allows achieving the maximum values of foaming resistance of their aqueous solutions, so probably even low-pressure treatment of the mixture during homogenization has a positive effect on this value.

The difference between the indicators of foam overrun and foam resistance for samples with non-hydrolyzed (C1–C5) and hydrolyzed (E1–E5) whey concentrates could also be explained by the lower viscosity of food systems with lactose hydrolysis products (Schmidt et al., 2016). This makes it possible to increase the total solids content without significantly changing the quality indicators of the ice cream.

To achieve the recommended degree of sweetness of ice cream (0.8–0.9) with non-hydrolyzed whey concentrate, the maximum possible replacement of sugar is to reduce its content from 15.5 to 11% while adding up to 30% of concentrate solids. As for ice cream with hydrolyzed concentrate, the maximum possible reduction in sugar content is more significant and reaches 9% in the case of adding up to 30% solids of the concentrate. Thus, the reduction in the need for sugar in ice cream with non-hydrolyzed whey concentrate can reach 29% (based on its total content), and with hydrolyzed concentrate – 42%.

In the case of the use of hydrolyzed concentrate, this indicator significantly exceeds the results of research by other scientists (Sofjan et al., 2004), who achieved only 25% sugar replacement. Even non-hydrolyzed concentrate due to its high lactose content is able to replace partially sugar, although the addition of lactose in such an amount in the composition of ice cream can lead to consistency defects. At the same time, the mass fraction of total solids in ice cream does not significantly decrease (McCain et al., 2018), which is a positive point, especially for low-fat ice cream with low amount of total solids.

Physicochemical properties of mixtures and ice cream with hydrolyzed and non-hydrolyzed whey concentrates

At the second stage, two samples of ice cream with non-hydrolyzed and hydrolyzed whey concentrates with maximum sugar replacement were selected (Table 2), according to the results of the previous series of experiments. Physicochemical indicators of mixtures and ice cream with whey concentrates are given in Table 3.

Table 2

Ice cream formulations with whey concentrates

Components	Weight of components, kg/1000 kg of product	
	Ice cream with non-hydrolyzed concentrate	Ice cream with hydrolyzed concentrate
Demineralized whey concentrate (40% total solids, of which protein is at least 4.4%)	750.0	750.0
White crystalline sugar	110.0	90.0
Stabilization system Cremodan SE 406	6.0	6.0
Vanillin	0.1	0.1
Water	133.9	153.9
Total	1000.0	1000.0

Table 3

Physicochemical indicators of mixtures and ice cream with whey concentrates

Physicochemical indicators	Ice cream with non-hydrolyzed concentrate	Ice cream with hydrolyzed concentrate
Total solids, %	41.61±0.41	39.61±0.40
including:		
– lactose	23.70±0.02	3.55±0.01
– protein	3.3±0.02	3.3±0.01
Water activity	0.955±0.015	0.911±0.017
Overrun, %	62.7±1.4	71.9±1.2
Resistance to melting, min	43.7±1.0	35.1±0.5

Ice cream with non-hydrolyzed and hydrolyzed concentrates differs in total solids by 2% (Table 3), which is due to a decrease in the need for sugar in the presence of monosaccharides. At the same time, the lactose content in the sample with unfermented concentrate is unacceptably high (23.7%), which can negatively affect the quality of the product during storage (Dekker et al., 2019), so the use of hydrolyzed whey concentrate is acceptable in ice cream. Usually, ice cream is a high-lactose product, because the average content of MSNF in it at the level of 10% ensures the presence of up to 5.2-5.5% lactose (Mykhalevych et al., 2022). Unlike ice cream with a traditional composition, ice cream based on hydrolyzed whey concentrate contains 6.7 times less lactose while being enriched with biologically complete protein. This is an important advantage of this author's development, which allows preventing excessive crystallization of lactose in ice cream (patent 4374861A US "Lactose-reduced ice cream and process for the production thereof").

Usually, the mass fraction of proteins in milk-based ice cream in the composition of MSNF ranges from 2.0 to 3.7% (Patel et al., 2006; Polishchuk et al., 2020), however, for amateur types of ice cream, in particular whey, this indicator may be lower at the level of 1.28-1.41% (Polishchuk et al., 2021; Young, 2007).

In both ice cream recipes, the content of high-value whey proteins is 3.3%, which fully corresponds to the standart protein content in ice cream for the formation of typical sensory and physicochemical indicators of this product.

One of the further directions for improving the composition of ice cream based on hydrolyzed whey concentrates may be additional enrichment of this product with proteins of various origins. Thus, it is known that protein enrichment of ice cream to a content of 7–8% is rational, as it improves the texture of the product and significantly reduces the size of ice crystals (Patel et al., 2006). At the same time, a higher protein content leads to a decrease in the overrun of ice cream due to the too high viscosity of the mixtures (Roy et al., 2022). Therefore, in order to assign ice cream to the category of products with a high protein content, in accordance with the requirements of EU Regulation No. 1924/2006 it is advisable to enrich this product with proteins of various origins.

As for the effect of hydrolyzed whey concentrates on the osmotic pressure of the aqueous phase of ice cream, a slightly lower activity of the water of the mixture with the hydrolyzed concentrate was found, compared to the activity of the water of the mixture with the non-hydrolyzed concentrate in the presence of monosaccharides as lactose hydrolysis products. The mixture with hydrolyzed whey concentrate is not a food system with intermediate moisture (Aw = 0.6–0.84) (Saha et al., 2020), but the high content of monosaccharides in it significantly affects the processes of forming the physicochemical parameters of ice cream as a polydisperse food system (Arslaner et al., 2019). In particular, the overrun of ice cream with hydrolyzed concentrate increases, but the resistance to melting decreases, compared to ice cream with non-hydrolyzed whey concentrate. It is clear that such changes are due to the presence of lactose hydrolysis products, which reduce the cryoscopic temperature and, accordingly, the dimensional stability of ice cream (Özdemir et al., 2008). Therefore, ice cream with monosaccharides, which has a soft consistency, must be packaged in a rigid consumer container.

In order to identify the possible influence of whey concentrate on the consistency and structure of ice cream, the rate of melting of experimental samples after their storage at minus (18±2) °C for up to 14 days was investigated (Figure 3). For both samples, the melting rate of ice cream decreases with the extension of storage time up to 2 weeks. At the same time, for a sample of ice cream with non-hydrolyzed whey concentrate, this indicator is lower, compared to a sample with hydrolyzed concentrate, due to a more significant decrease in the content of sugar as a cryoprotectant (Maity et al., 2018). In addition, the cryoscopic temperature is indirectly affected by lactose (Mullan, 2015), the hydrolysis of which leads to a decrease in melting resistance (Matak et al., 2003). On the other hand, the influence of monosaccharides on the stability of the ice cream structure during storage is not critical and does not lead to a significant deterioration in the quality of the finished product, as described (Arslaner et al., 2019; Whelan et al., 2008). This effect can be attributed to the sufficient content of whey proteins, which bind excess moisture and prevent the ice cream from quick melting (Young et al., 2007).

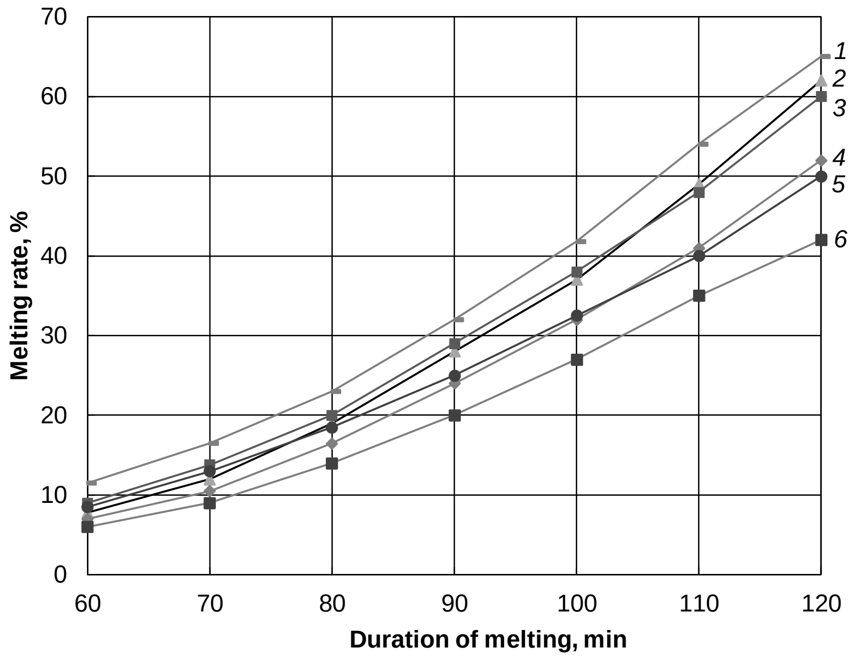


Figure 3. Melting rate of ice cream with non-hydrolyzed (NHC) and hydrolyzed (HC) whey concentrates after 24 hours of production (24 h), one week (1 w) and 2 weeks (2 w) of storage:
1, HC after 24 h;
2, NHC after 24 h;
3, HC after 1 w;
4, NHC after 1 w;
5, HC after 2 w;
6, NHC after 2 w.

At the next stage, the viscosity-speed characteristics of mixtures and ice cream with demineralized whey concentrates were investigated, which are listed in Table 4.

Table 4
Viscosity-speed characteristics of ice cream mixtures with demineralized whey concentrates

Ice cream mixture	Effective viscosity (mPa·s) under variable shear rate gradient (γ)			The time of ultimate destruction of the structure (γ= 1312 s^{-1}), min	The degree of structure recovery, %
	γ= 3 s^{-1} (straight course)	γ= 1312 s^{-1}	γ= 3 s^{-1} (reverse course)		
with non-hydrolyzed concentrate	652.2±15.6	26.0±1.1	403.2±11.8	6.6±0.2	61.8
with hydrolyzed concentrate	601.0±11.8	20.0±1.0	350.3±10.5	5.5±0.2	58.2

The effective viscosity of low-fat ice cream mixtures, based on whey concentrates, is close to the values of this indicator, characteristic of ice cream mixes with a high fat content (Syed et al., 2018). The increased content of whey proteins and solids contributes to the additional structuring of mixtures that contain the Cremodan SE 406 stabilization system. This eliminates the lack of fat as a structuring agent in the composition of ice cream. As for the comparison of the values of the effective viscosity of both mixtures, a slight decrease in the structuring ability of the mixture with the hydrolyzed concentrate should be noted. This is because disaccharides have a greater effect on the viscosity of solutions in the presence of proteins, compared to monosaccharides. Scientists explain this effect by generally accepted mechanisms of interaction between sugar and protein molecules in water solutions (He et al., 2011). The increased effective viscosity of mixtures, based on whey concentrates, compared to the viscosity of milk low-fat ice cream mixtures, to some extent neutralizes the negative effect of monosaccharides on the melting resistance of the hardened product (Table 3). At the same time, the too low effective viscosity of low-fat and non-fat mixtures of standard composition does not ensure proper stabilization of the formed dispersed ice cream systems (He et al., 2011). The effective viscosity of the restored structure of mixtures with whey concentrates reveals a pronounced thixotropic ability in the presence of an increased content of whey proteins. Such mixtures can be attributed to systems with a pronounced coagulation structure, with the detection of thixotropic properties.

Sensory evaluation of ice cream with demineralized whey concentrates

A sensory evaluation of ice cream with a concentrate of non-hydrolyzed and hydrolyzed whey was carried out using the descriptive-integral method (Table 5).

The comparative analysis of the integral assessment of sensory indicators, along with other positive characteristics, listed in the Table 3, gives reason to recommend ice cream based on hydrolyzed demineralized whey for the development of original recipes. Mahmood and Mahmood (2017) reported that ice cream samples with hydrolyzed lactose at the level of 28–56% did not have a significant difference in the degree of sweetness from ice cream with non-hydrolyzed lactose, increasing the degree of lactose hydrolysis to 85% already has a noticeable effect on the degree of sweetness ice cream. Other researchers have reported the sensation of smaller ice crystals in frozen hydrolyzed desserts compared to non-hydrolyzed ones (Skryplonek et al., 2017), however, El-Nagar et al. (2002) found unsatisfactory sensory characteristics of low-fat frozen yogurt due to the presence of coarse crystalline structure and consistency. Another advantage of ice cream with hydrolyzed whey concentrate is its plastic and delicate consistency due to the presence of monosaccharides – glucose and galactose, the influence of which on the consistency of ice cream and frozen desserts was noted by other scientists (Skryplonek et al., 2017).

Prospects for further research consist in conducting a comparative analysis of the effectiveness of the use of hydrolyzed demineralized whey concentrates with different solids content in low-fat and non-fat ice cream, as well as in additional enrichment of ice cream with proteins of various origins.

Table 5

Sensory evaluation of ice cream with whey concentrates

Descriptor	**Overall score, points**	
	Ice cream with non-hydrolyzed concentrate	Ice cream with hydrolyzed concentrate
Criterion 1. Appearance		
Finely dispersed air bubbles	5.0	5.0
Homogeneity of mass	5.0	5.0
Foam overrun	4.4	5.0
Small ice crystals	4.0	4.5
Form stability	4.6	4.1
Criterion 2. Smell and odor		
Sweet	5.0	5.0
Sour milk	3.8	4.1
Lactic	4.8	4.9
Whey	5.0	5.0
Absence of extraneous odors	5.0	5.0
Criterion 3. Color		
Yellow	3.5	3.8
Dark yellow	4.8	5.0
Deep yellow	5.0	5.0
Homogeneous	5.0	5.0
Attractive	3.9	4.4
Criterion 4. Consistency		
Overrun	4.1	4.5
A mass that does not melt quickly	3.9	3.0
Without sandiness	3.2	4.6
Homogeneous	4.0	4.7
Small ice crystals	4.6	4.9
Criterion 5. Taste and aftertaste		
Sour milk	3.8	3.3
Whey	5.0	4.8
Lactic	4.9	5.0
Sweet	5.0	5.0
Without a sweet aftertaste	3.6	5.0
Integral evaluation	**88.72**	**92.48**

Conclusions

1. The concentrate of demineralized hydrolyzed whey with total solids content 40% can replace up to 42% of sugar in the composition of ice cream, while maintaining the degree of sweetness determined for this type of ice cream in the range from 0.8 to 0.9.
2. According to the viscosity-speed characteristics, the mixture of low-fat ice cream with the concentrate of demineralized hydrolyzed whey can be attributed to systems with a pronounced coagulation structure with the detection of thixotropic properties. The

effective viscosity of the mixture is close to the values of this indicator, characteristic of ice cream mixtures with a high fat content. Ice cream mixes with hydrolyzed whey concentrate have a higher foam overrun and stability due to lower viscosity, which allows maximum replacement of sugar with whey concentrate solids.

3. Ice cream based on hydrolyzed concentrate contains 3.3% protein, which corresponds to the standard chemical composition of ice cream. The high content of lactose hydrolysis products in ice cream increases overrun, melting rate, improves consistency, but reduces the resistance to melting of ice cream, which must be taken into account during the technological process and when choosing a consumer container.

Acknowledgments. The work was carried out at the National University of Food Technologies (Kyiv, Ukraine) within the framework of the state RandD projects "Implementation of resource-saving methods of modifying the techno-functional characteristics of milk whey in the technologies of food products for the purpose targets" (state registration number: No. 0120U100868) and "Scientific substantiation of resource-efficient technologies of food products enriched with polyfunctional ingredients" (state registration number: No. 0120U102556).

References

Abbasi S., Saeedabadian A. (2015), Influences of lactose hydrolysis of milk and sugar reduction on some physical properties of ice cream, *Journal Food Science Technology*, 52, pp. 367–374, DOI: 10.1007/s13197-013-1011-1.

Akalın A.S., Karagözlü C., Ünal G. (2008), Rheological properties of reduced-fat and low-fat ice cream containing whey protein isolate and inulin, *European Food Research and Technology*, 227(3), pp. 889–895.

Aljewicz M., Florczuk A., Dąbrowska A. (2020), Influence of β-glucan structures and contents on the functional properties of low-fat ice cream during storage, *Polish Journal of Food and Nutrition Sciences*, 70(3), pp. 233–240, DOI: 10.31883/pjfns/120915.

Alvarez V.B., Wolters C.L., Vodovotz Y., Ji T. (2005), Physical properties of ice cream containing milk protein concentrates, *Journal of Dairy Science*, 88(3), pp. 862–871, DOI: 10.3168/jds.S0022-0302(05)72752-1.

Arsić S., Bulatović M., Rakin M., Sredojević Z. (2019), Production and techno-economic opportunities of use of whey in industrial processes. *Scientific Papers. Series Management, Economic Engineering in Agriculture and Rural Development*, 19(1), pp. 41–45.

Arslaner A., Salık M. A., Özdemir S., Akköse A. (2019), Yogurt ice cream sweetened with sucrose, stevia and honey: Some quality and thermal properties, *Czech Journal of Food Sciences*, 37(6), pp. 446–455.

Atallah A.A., Morsy O.M., Abbas W., Khater E.G. (2022), Microstructural, physicochemical, microbiological, and organoleptic characteristics of sugar- and fat-free ice cream from buffalo milk, *Foods (Basel, Switzerland)*, 11(3), 490, DOI: 10.3390/foods11030490.

Bass O., Polischuk G., Goncharuk O. (2018), Influence of sweeteners on rheological and qualitative indicators of ice cream, *Ukrainian Food Journal*, 7(1), pp. 41–53, DOI: 10.24263/2304-974X-2018-7-1-5.

Carrasco J.L., Jover L. (2005), Concordance correlation coefficient applied to discrete data, *Statistics In Medicine*, 24, pp. 4021–4034, DOI: 10.1002/sim.2397.

Chauhan J.M., Lim S-Y., Powers J.R., Ross C.F., Clark S. (2010), Short communication: low-fat ice cream flavor not modified by high hydrostatic pressure treatment of whey protein concentrate, *Journal of Dairy Science*, 93 (4), pp. 1452–1458, DOI: 10.3168/jds.2009-2688.

Cherevychna N., Haponceva O. (2019), Modern white quality assessment systems of wine, *Young Scientist*, 5(69), pp. 281-286, DOI: 10.32839/2304-5809/2019-5-69–62.

Dekker P.J.T., Koenders D., Bruins M.J. (2019), Lactose-free dairy products: market developments, production, nutrition and health benefits, *Nutrients*, 11(3), 551, DOI: 10.3390/nu11030551.

El-Nagar G., Clowes G., Tudorică C.M., Kuri V., Brennan C.S. (2002), Rheological quality and stability of yog-ice cream with added inulin, *International Journal Dairy Technology*, 55(2), pp. 89–93.

El-Zeini Hoda M., Moneir El-Abd. M., Mostafa A.Z., Yasser El-Ghany F.H. (2016), Effect of incorporating whey protein concentrate on chemical, rheological and textural properties of ice cream, *Journal of Food Process Technology*, 7(546), pp. 1–7, DOI: 10.4172/2157-7110.1000546.

Ganga S.M., Ashish K.S., Narender R.P. Sumit A. (2017), Milk protein concentrates: opportunities and challenges, *Journal of Food Science and Technology*, pp. 3010–3024, DOI: 10.1007/s13197-017-2796-0.

Goff H.D. (2018), Reference module in food science, *Ice cream and frozen desserts: Product types (pp. 1-6)*, UK: Elsevier, Oxford.

Goff H.D., Guo Q. (2019), Handbook of food structure development, *The Role of Hydrocolloids in the Development of Food Structure (pp. 1–28)*, Royal Society of Chemistry.

He F., Woods C., Litowski J.R., Roschen L., Gadgil H.S., Razinkov V.I., Kerwin B.A. (2011), Effect of sugar molecules on the viscosity of high concentration monoclonal antibody solutions, *Pharmaceutical Research*, 28, pp. 1552–1560, DOI: 10.1007/s11095-011-0388-7.

Hinkova A., Bubnik Z., Kadlec P. (2015), Handbook of food chemistry, *Chemical Composition of Sugar and Confectionery Products (pp. 585–626)*, Berlin: Springer.

İbanoğlu E., Karataş Ş. (2001), High pressure effect on foaming behaviour of whey protein isolate, *Journal of Food Engineering*, 47(1), pp. 31–36.

Kuzmyk U., Marynin A., Svyatnenko R., Zheludenko Y., Kurmach M., Shvaiko R. (2021), Prospects of use of vegetable raw materials in the technology of sour-milk dessert, *EUREKA: Life Sciences*, (3), pp. 29–35, DOI: 10.21303/2504-5695.2021.001848.

Lim S.Y., Swanson B.G., Clark S. (2008a), High hydrostatic pressure modification of whey protein concentrate for improved functional properties, *Journal of dairy Science*, 91(4), pp. 1299–1307, DOI: 10.3168/jds.2007-0390.

Lim S.Y., Swanson B.G., Ross C.F., Clark S. (2008b), High hydrostatic pressure modification of whey protein concentrate for improved body and texture of lowfat ice cream, *Journal of Dairy Science*, 91(4), pp. 1308–1316, DOI: 10.3168/jds.2007-0391.

Livney Y.D., Donhowe D.P., Hartel R.W. (2007), Influence of temperature on crystallization of lactose in ice-cream, *International Journal of Food Science and Technologies*, 30(3), pp. 311–320, DOI: 10.1111/j.1365-2621.1995.tb01380.x.

Mahmood W., Mahmood K.T. (2012), Application of enzymatically hydrolyzed-lactose milk and whey in some dairy products, *Mesopotamia Journal of Agriculture*, 45, 1, pp. 329–340, DOI: 10.33899/magrj.2012.161258.

Maity T., Saxena A., Raju, P.S. (2018), Use of hydrocolloids as cryoprotectant for frozen foods, *Critical reviews in food science and nutrition*, 58(3), pp. 420–435.

Majore K., Ciproviča I. (2020), *Optimisation of lactose hydrolysis by combining solids and ß-galactosidase concentrations in whey permeates*, Proceedings of the Latvian Academy of Sciences, Section B. Natural, Exact, and Applied Sciences, 74(4), pp. 263–269, DOI: 10.2478/prolas-2020-0041.

Marshall R.T., Goff H.D., Hartel R.W. (2003), Ice cream, *The Ice Cream Industry (pp. 1-9)*, US: Springer, Boston.

Matak K.E., Wilson J.H., Duncan S.E., Wilson E.J., Hackney C.R., Sumner S.S. (2003), The influence of lactose hydrolysis on the strength and sensory characteristics of vanilla ice cream, *Transactions of the ASAE*, 46(6), 1589.

McCain H.R., Kaliappan S., Drake M.A. (2018), Invited review: Sugar reduction in dairy products, *Journal of Dairy Science*, 101(10), pp. 8619–8640, DOI: 10.3168/jds.2017-14347.

Mitchell H. (2008), *Sweeteners and sugar alternatives in food technology*, UK: John Wiley and Sons.

Mullan W.M.A. (2015), Perfect ice cream or gelato. Getting the hardness or “scoopability” just right. Available at: https://www.dairyscience.info/index.php/ice-cream/228-ice-cream-hardness.html.

Muse M.R., Hartel R.W. (2004), Ice cream structural elements that affect melting rate and hardness, *Journal of Dairy Science*, 87(1), pp. 1–10, DOI: 10.3168/jds.S0022-0302(04)73135-5.

Mykhalevych A., Kostenko O., Polishchuk G., Bandura U. (2022), Application of milk protein concentrates in preparation of reduced fat sour cream, *Ukrainian Food Journal*, 11(3), pp. 429–447, DOI: 10.24263/2304-974X-2022-11-3-8.

Mykhalevych A., Polishchuk G., Nassar K., Osmak T., Buniowska-Olejnik M. (2022), β-Glucan as a techno-functional ingredient in dairy and milk-based products—a review, *Molecules*, 27(19), 6313, DOI: 10.3390/molecules27196313.

Nasser S., Hedoux A., Giuliani A., Floch-Fouéré C., Sante-Lhoutellier V., de Waele, I., Delaplace G. (2018), Investigation of secondary structure evolution of micellar casein powder upon aging by FTIR and SRCD: consequences on solubility, *Journal of the Science of Food and Agriculture*, 98, pp. 2243–2250. DOI: 10.1002/jsfa.8711.

Nastaj M., Sołowiej B.G., Gustaw W., Peréz-Huertas S., Mleko S., Wesołowska-Trojanowska M. (2019), Physicochemical properties of high-protein-set yoghurts obtained with the addition of whey protein preparations, *International Journal of Dairy Technology*, 72 (3), pp. 395–402, DOI: 10.1111/1471-0307.12603.

Osmak T., Mleko S., Bass O., Mykhalevych A., Kuzmyk U. (2021), Enzymatic hydrolysis of lactose in concentrates of reconstituted demineralized whey, intended for ice cream production, *Ukrainian Food Journal*, 10(2), pp. 277–288, DOI: 10.24263/2304- 974X-2021-10-2-6.

Özdemir C., Arslaner A., Özdemir S., Özdemir G.U.C. (2018), Ice-cream production from lactose-free UHT milk, *Journal of Food Science and Engineering*, 8, pp. 210–214, DOI: 10.17265/2159-5828/2018.05.003.

Özdemir C., Dağdemir E.U., Özdemir S., Sağdıç O. (2008), The effects of using alternative sweeteners to sucrose on ice cream quality, *Journal of Food Quality*, 31, pp. 415–428, DOI: 10.1111/J.1745-4557.2008.00209.X.

Patel M.R., Baer R.J., Acharya M.R. (2006), Increasing the protein content of ice cream, *Journal of Dairy Science*, 89(5), pp. 1400–1406.

Pei Z.J., Schmidt K.A. (2010), Ice cream: foam formation and stabilization—a review, *Food Reviews International*, 26(2), pp. 122–137, DOI: 10.1080/87559120903564472.

Peng Y., Serra M., Horne D.S., Lucey J.A. (2009), Effect of fortification with various types of milk proteins on the rheological properties and permeability of nonfat set yogurt, *Journal Food Science*, 74(9), pp. 666–673, DOI: 10.1111/j.1750-3841.2009.01350.x.

Polishchuk G., Breus N., Shevchenko I., Gnitsevych V., Yudina T., Nozhechkina-Yeroshenko G., Semko T. (2020), Determining the effect of casein on the quality indicators of ice cream with different fat content, *Eastern-European Journal of Enterprise Technologies*, 4(11(106), pp. 24–30, DOI: 10.15587/1729-4061.2020.208954.

Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods. Available at: https://eur-lex.europa.eu/legal-content/en/ALL/?uri= CELEX%3A32006R1924

Romanchuk I., Minorova A., Krushelnytska N. (2018), Physical-chemical composition and technological properties of demineralized milk whey received by membrane methods, *Agricultural Science and Practice*, 5(3), pp. 33–39, DOI: 10.15407/agrisp5.03.033.

Roy S., Hussain S.A., Prasad W.G., Khetra Y. (2022), Quality attributes of high protein ice cream prepared by incorporation of whey protein isolate, *Applied Food Research*, 2(1), 100029, DOI: 10.1016/j.afres.2021.100029.

Saha S. (2020), IMF: To enhance the shelf-life of food, *Technology*, 6(10), pp. 103–108, DOI: 10.1016/j.afres.2021.100029.

Schmidt C., Mende S., Jaros D., Rohm H. (2016), Fermented milk products: effects of lactose hydrolysis and fermentation conditions on the rheological properties, *Dairy Science and Technology*, 96, pp. 199–211, DOI: 10.1007/s13594-015-0259-9.

Schmidt C., Mende S., Jaros D., Rohm H. (2016), Fermented milk products: effects of lactose hydrolysis and fermentation conditions on the rheological properties, *Dairy Science and Technology*, 96(2), pp. 199–21, DOI: 10.1007/s13594-015-0259-9.

Skryplonek K., Gomes D., Viegas J., Pereira C., Henriques M. (2017), Lactose-free frozen yogurt: production and characteristics, *Acta Scientiarum Polonorum Technologia Alimentaria*, 16(2), pp. 171–179, DOI: 10.17306/J.AFS.2017.0478.

Sofjan R.P., Hartel R.W. (2004), Effects of overrun on structural and physical characteristics of ice cream, *International Dairy Journal*, 14, pp. 255–262, DOI: 10.1016/j.idairyj.2003.08.005.

Syed Q.A., Anwar S., Shukat R., Zahoor T. (2018), Effects of different ingredients on texture of ice cream, *Journal of Nutritional Health and Food Engineering*, 8(6), pp. 422–435, DOI: 10.15406/jnhfe.2018.08.00305

Trubnikova A., Chabanova O., Sharahmatova T., Bondar S., Vikul S. (2018), Justification and development of recipes of low-lactose biologically active milk ice cream, *Path of Science*, 4(9), pp. 3001–2021, DOI: 10.22178/pos.38-7.

Trumbo P.R., Appleton K.M., de Graaf K., Hayes J.E., Baer D.J., Beauchamp G.K., Dwyer J.T., Fernstrom J.D., Klurfeld D.M., Mattes R.D., Wise P.M. (2021), Perspective: measuring sweetness in foods, beverages, and diets: toward understanding the role of sweetness in health, *Advances in N utrition (Bethesda, Md.)*, 12(2), pp. 343–354, DOI: 10.1093/advances/nmaa151.

Tsuchiya A.C., Monteiro da Silva A.G., Brandt D., Kalschne D.L.,. Drunkler D.A., Colla E. (2017). Lactose reduced ice cream enriched with whey powder, *Semina: Ciencias Agrarias*, 38(2), 749, DOI: 10.5433/1679-0359.2017v38n2p749.

Whelan A.P., Vega C., Kerry J.P., Goff H.D. (2008), Physicochemical and sensory optimisation of a low glycemic index ice cream formulation, *International Journal of Food Science and Technology*, 43, pp. 1520–1527, DOI: 10.1111/j.1365-2621.2007.01502.x.

Wildmoser H., Scheiwiller J., Windhab E.J. (2004), Impact of disperse microstructure on rheology and quality aspects of ice cream, *LWT-Food Science and Technology*, 37, pp. 881–891, DOI: 10.1016/j.lwt.2004.04.006.

Wilson J.H., Duncan S.E., Wilson E.J., Hackney C.R., Sumner S.S. (2003), The influence of lactose hydrolysis on the strength and sensory characteristics of vanilla ice cream, *Transactions of the ASAE*, 46(6), pp. 1589–1593, DOI: 10.13031/2013.15621.

Young S. (2007), *Whey products in ice cream and frozen dairy desserts,* Applications Monograph.

Management of apple and grape processing by-products. A review

Viktorija Stamatovska[1], Gjore Nakov[2]

1 – "St. Kliment Ohridski" University of Bitola, Faculty of Technology and Technical Science, R.N. Macedonia
2 – Technical University of Sofia, College of Sliven, Bulgaria

Keywords:

By-products
Grape
Apple
Pomace
Waste
Functional

Article history:

Received 25.08.2022
Received in revised form 10.12.2022
Accepted 30.12.2022

Corresponding author:

Gjore Nakov
E-mail: gnakov@tu-sofia.bg

DOI: 10.24263/2304-974X-2022-11-4-4

Abstract

Introduction. The by-products from the processing of apples and grapes can be excellent materials for the production of functional foods. In this case, the environment is preserved, and food products are enriched with important nutrients.

Materials and methods. A systematization of the latest scientific research in terms of management of the waste from the production of apple juice and grape wine.

Results and discussion. By-products of apple and grape processing contain important nutrients such as fibers, minerals, vitamins, polyphenols, and possess high antioxidant activity. In recent years, a lot of research has been conducted to study the application of this type of waste in preparation of different food products (biscuits, cookies, cakes, bread, pasta, noodles, yogurt, cheese, kefir, salami, sausages, patties, and burgers). Regarding the percentages of substitution of conventional flours with by-products of apple and grape processing, variations are observed. For cereal products, the minimum percentage of substitution was 1% and the maximum was 100%. For meat products, the percentages of added by-products of apple and grape processing varied from 1 to 20%, while for dairy products, these contents were between the values of 0.2 and 10%. An improvement in nutrient quality with the addition of by-products of apple and grape processing was observed, such as increase of fiber, total polyphenol, flavonoids, anthocyanins and mineral contents and antioxidant activity. Incorporation of apple and grape processing by-products leads to changes of the volume or height of the products (biscuits, cookies, cakes, and bread), and changes in texture (hardness, crunchiness), appearance (surface properties, color, density), and intensity of smell and taste. It was found that the optimum cooking time of pasta/noodles/spaghetti decreased and cooking loss increased with the increasing amount of incorporated apple and grape processing waste. Addition of these by-products reduced fermentation time and syneresis during yogurt storage. It was found that the addition of by-products of apple and grape processing in the meat products increased cooking yield, emulsion stability, radical scavenging activity, and decreased pH.

Conclusions. Use of waste from the processing of apples and grapes in the food industry is an opportunity to reduce environmental pollution, to create new functional and innovative food products, which will be enriched with important nutrients and biologically active substances.

Introduction

The by-products of fruit processing are rich with nutrients and bioactive compounds and can be used as ingredients for functional food production (Stabnikova et al., 2021). In recent decades, the demand for functional food with bioactive compounds has increased, and the food industry is constantly improving and reaching new sustainable solutions for the production of food using the by-products of plant origin (Colantuono, 2019; Ivanov et al., 2021).

During processing of fruits for production of juices, wine, jams, canned fruits and others, various fruit by-products are created, which are belonging to so called "food waste", which can be considered as additional sources of valuable raw materials to be used in manufacturing of new products (Galanakis et al., 2012).

By-products released in the processing of apples are presented by skins, peels, seeds, stems, flesh, pulps, and pomace (Figure 1), and skins, stalks, pulp, seeds and pomace are accumulated during grape processing (Figure 2).

Skins or peels are one of the by-products most often thrown away during fruit processing. Pomace is the remaining solid after juice extraction and usually consists from remaining seeds, skins, pulp and stems of the fruit (Lau et al., 2021). For example, apple pomace is a heterogeneous mixture composed mainly of skin and flesh, 95%, while the seeds and stems are represented by a smaller percentage, 2-4% and 1%, respectively (Lyu et al., 2020).

Grape pomace is composed of seeds, 22.5%, skins, 42.5%, stalks, 24.9%, and other minor constituents (e.g., water) (Spinei et al., 2021).The amount of by-products that are created from processed fruit varies depending on the type of product to be obtained, the type of fruit, its variety, the size and the stage of maturity (Larrosa et al., 2021).

Grape pomace, the main by-product of wine production, consists up to 20-25% of the weight of grapes crushed used for wine production (Yu et al., 2013). Apple pomace, the main by-product of apple juice production, accounts for 25-30% of all fresh apple fruit processed (Lyu et al., 2020). It is well known that fruit by-products are an important source of carbohydrates, minerals, vitamins, organic acids, raw proteins, dietary fiber, carotenoids, polyphenolic compounds, and other nutritionally significant components (Fierascu et al., 2020) and possess antioxidant, antimicrobial, anti-carcinogenic, antiviral, and antibacterial activities (Leyva-López et al., 2020).

The amount and composition of biological useful components in fruit by-products vary depending on the type of fruit, its variety, the climatic conditions in which it is grown and the way it is processed (Erinle et al., 2022). The composition of dry apple pomace includes carbohydrates: 18–31% fructose, 3.4-24% sucrose, and 2.5-12.4% glucose (Waldbauer et al., 2017), dietary fiber, 35-60%, with a high amount of insoluble fiber, 36.5%, as well as soluble fiber, 14.6% (Dhillon et al., 2013), small amounts of protein, fat, and ash, high content of phytochemicals primarily phenolic acids and flavonoids. Some of the phenolic compounds identified in apple pomace possess antioxidant capacities (Reis et al., 2014). Grape pomace is known to be a source of proteins, mean value of 10% on DW, as well as minerals, especially iron (18 mg/100 g DW), dietary fiber (approx. 50% on dry weight (DW)), and phenolic compounds such as flavonols, catechins, anthocyanins, and phenolic acids (Balli et al., 2021). However, apple and grape processing by-products contain a large amount of water, which makes them susceptible to rapid spoilage. In order to obtain stable products with a long shelf life, most often they are dried. Various drying techniques can be used to prolong shelf life, to avoid microbiological contamination, and to preserve nutrients, bioactive compounds, and antioxidant activity. In addition, dry by-products are ground to reduce particle size, and standardization of grain size is recommended (Larrosa et al., 2021).

Potentially valuable compounds of the by-products of apple and grape processing can be used as nutrients in people's diets. Using by-products is one option to avoid environmental problems and help the economy and society. This review summarizes some of the available literature related to the use of the by-products from apple and grape processing in human nutrition.

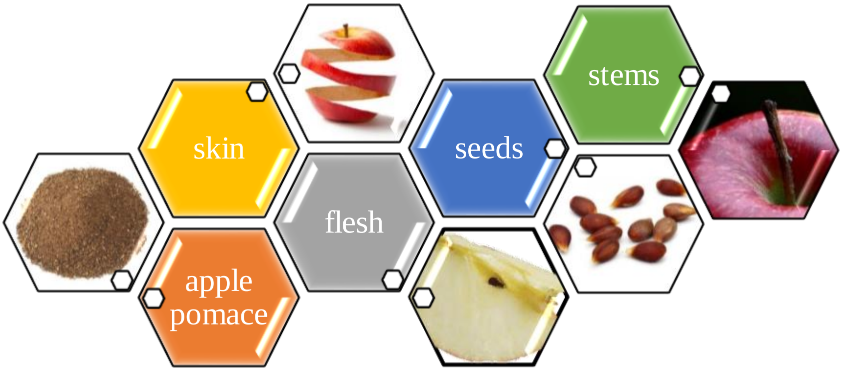


Figure 1. By-products from apple processing

Figure 2. By-products from grape processing

Materials and methods

The materials used in this review cover information from the authors who focus on the most recent trends in the management of waste (fruit by-products). Material for the research served as literary sources in which the current food applications of by-products of apple and grape processing and the influence of their addition on the characteristics of food products are exposed. Literature referenced in this review article was obtained from bibliographic information in Google Scholar, Web of Science, Science Direct, Scopus, Springer Link, EBSCO host, Wiley online library, and PubMed.

Results and discussion

Utilization of fruit processing by-products

Fruit by-products have gained importance as a functional ingredient due to their superior nutritional properties (Bora et al., 2019). There have been numerous reports of the use of by-products derived from the processing of various types of fruit in the food industry. The authors design foods with different applications of fruit by-products as a supplement. Usually, fruit processing by-products are dried, ground and added to products prepared from flour or in yogurt, milk, and cheese (Larrosa et al., 2021). The advantages of adding fruit processing by-products include improved nutritional properties of the products, increasing of total phenolic content, total flavonoid content, antioxidant activity and dietary fiber content. In addition, some qualitative, technological and sensory properties of those food products can be improved (Piasecka et al., 2020). The dried fruit pomace can be used in bakery products as a substitute for flour, sugar or fat, increasing the amount of fiber and antioxidants and reducing energy consumption (Djeghim et al., 2021).The most studied products enriched with fruit by-products are: bread, muffins, cakes, cookies, biscuits, snack products, and pasta (Piasecka et al., 2020).

Utilization of apple processing by-products

The by-products obtained in the processing of apples have a significant potential for application in the production of nutritionally enriched food prepared from flour, because of its favorable nutritional profile due to the presence of phenolic compounds and dietary fiber and good sensory characteristics, namely pleasant fruity aroma. Their addition to food products increases in the amount of dietary fiber and polyphenols and prevents undesirable oxidation reactions caused by the action of free radicals, which affects the quality and sustainability of the product itself, as well as consumer health (Sudha et al., 2016). Different applications of apple pomace are shown in Figure 3.

Multiple reports of studies are available on the enrichment of flour products by adding apple processing by-products. Karkle et al. (2012) prepared corn-based extrudates in which they added 17%, 22%, and 28% apple pomace. The added pomace did not adversely affect the mechanical properties and structure of the products and contributed to a fruity aroma and a greater share of dietary fiber and polyphenols.

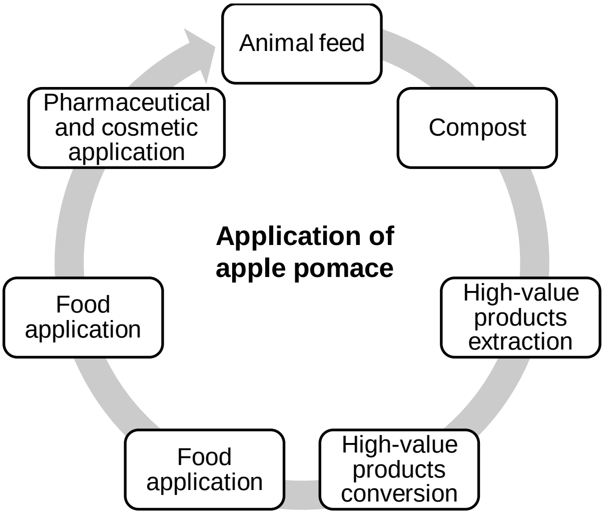


Figure 3. Application of apple pomace

Jung et al. (2015) prepared cookies and muffins replacing 10% and 20% of wheat flour with apple pomace. The partial substitution of wheat flour with apple pomace (up to 20%) had a positive effect on the physical-chemical and sensory characteristics of cookies and muffins. The addition of apple pomace to brown rice flour in the formulation of gluten free crackers in a proportion of 3, 6, and 9% resulted in better antioxidant properties, higher polyphenol content, total dietary fiber and minerals, and sensory acceptability (Mir et al., 2017). A higher value for total dietary fiber content compared to a control wheat sponge cake was determined by Torbica et al. (2018), who substituted wheat flour in the formulation for a sponge cake with apple pomace coextruded with corn grit in a ratio of 45:55.

The use of the apple pomace can affect the reduction of the glycemic index of the products to which it is added, while not affecting sensory descriptors, such as taste, sweetness, acidity, hardness and crunchiness. Alongi et al. (2019) produced biscuits replacing wheat flour (10 and 20%) with apple pomace powder and found a decrease in the glycemic index, from a glycemic index of 70 to a glycemic index of 65 and 60 respectively, and were ranked as products with a mean glycemic index.

Apple skin powder replaced with wheat flour in the production of muffins in an amount of up to 16% increased the share of dietary fiber and polyphenolic compounds, while not worsening sensory characteristics (Rupasinghe et al., 2008; 2009). Research conducted by Nakov et al. (2020) found that apple peel powder-enriched cookies (4, 8, 16, 24 and 32%) had significantly higher moisture, ash, lipid, fiber, total polyphenols, and antioxidant capacity than control cookies. The addition of apple peel powder did not worsen the physical characteristics of the products but helped to improve their sensory quality. Cookies with 24% apple peel powder proved to be the best in terms of appearance, internal structure, texture, and taste.

Several studies have focused on noodles and bread enriched with apple pomace. Apple pomace powder is incorporated into noodles at three different levels (10, 15 and 20%). Noodles enriched with apple pomace had a higher total dietary fiber and protein content, and showed improved antioxidant activity compared to control noodles. Analyses of cooking characteristics, such as texture, quality, color, and sensory evaluation, found that noodles enriched with 10% apple pomace powder were the most acceptable product in terms of both taste and nutritional composition (Suman et al., 2015). The addition of a 5% to 10% of apple pomace has been shown to be best when enriching Chinese raw pasta (Xu, 2020). Bchir et al. (2022) studied the impact of incorporating the by-products of pear, date, and apples processing on the properties of pasta. From the overall results, it was concluded that the by-products have a positive impact on the physical-chemical properties and quality attributes of pasta. Pasta with a 2.5% share of by-products proved to be the most acceptable.

Jannati et al. (2018) rated the quality of traditional Iranian bread that had apple pomace powder added to it (1, 3, 5 and 7% w/w of flour). The results showed that adding the apple pomace powder can reduce the hardness of the bread, and the color of the crust of the bread added with apple pomace was darker compared to the bread without pomace powder. Sensory analysis showed that adding up to 3% of the pomace can improve the aroma, texture, and overall acceptability of bread. Bread formulated with gluten-free raw materials has low nutritional properties, poor taste, and is of poorer quality, and due to the absence of gluten, the dough has poor rheological properties and is unable to develop a protein network, which affects the final quality of the resulting bread. Adding fruit by-products such as apple processing by-products to a gluten-free bread formulation can improve the texture, mouth feel, acceptability, shelf life, and nutritional properties of gluten-free bread (Djeghim et al., 2021). Apple pomace also has a high potential to be used as a natural stabilizer and texturizer in the fermentation of yogurt, while enriching the final product with dietary fiber and phytochemicals (Wang et al., 2019). Studies of the sensory and textural characteristics of probiotic yogurts indicate that apple pomace flour can be added in the optimal amount of 3% (Jovanović et al., 2020).

Most studies to date have emphasized the use of apple pomace in meat products such as salami (Grispoldi et al., 2022), chicken sausages (Choi et al., 2016), beef burgers (Pollini et al., 2022), chicken patties (Junget al., 2015), buffalo meat patties (Younis and Ahmad, 2018), and buffalo meat sausages (Younis and Ahmad, 2015) to improve nutritional properties, reduce fat content and energy value, increase the content of dietary fiber and antioxidants. The obtained results confirm an increased content of dietary fiber and phenols, along with lower values for fat and calories in enriched meat products with apple pomace. The summary of the various studies on application of apple pomace in food product preparation is presented in Table 1.

Table 1

Application of apple pomace in food product preparation

Food product	Apple pomace	Results	References
Extruded products	Added, 10-30% on a dry weight basis	Increased fiber and phenolic content, antioxidant capacity.	Reis et al.,2014
	Added, 5-20% w/w	Increased bulk density, total phenolic content, and antioxidant activity.	Singha et al., 2018
	Added, up to 30 %	Increased total contents of phenols and antioxidant activity.	León et al.,2022
Gluten-free cakes	Replacement of rice flour, 5–15%.	Increased elastic modulus, viscosity, specific gravity, and crumb hardness. Decreased specific volume.	Kırbaș et al., 2019

Food product	Apple pomace	Results	References
Muffins	Replacement of wheat flour, 10% and 20%	No detrimental effects on the physicochemical and textural properties.	Junget al.,2015
	Addition of apple pomace powder, 5, 10, and 15%.	Increased ash, fiber, and phenolic contents. Decreased protein and moisture contents. Muffins with 10% of apple pomace had higher sensory evaluation.	Younas et al.,2015
Cookies	Replacement apple pomace flour, 10 and 20%	No detrimental effects on the physicochemical and textural properties.	Junget al.,2015
	Replacement of flour, 5, 10, and 15% with hydrated apple pomace powder.	Reduced physical properties (volume, diameter, porosity). Increased the rheological properties of dough (water absorption, stability). Prolonged dough development time and reduced the mixing tolerance index. High overall acceptance.	Lauková et al.,2016
	Addition of apple pomace powder, 5, 10, 15, 20, and 25% to wheat flour	Increased water absorption, dough development time, dough stability, and falling number. Decreased width, and thickness, and increased spread factor. Reduced color. Increased moisture, ash, crude fat, and crude fiber contents. Good quality cookies with improved organoleptic properties can be prepared using 10%.	Usmanet al.,2020
Bread	Addition of apple pomace, 1, 2, 3, and 4% (60-mesh and 100-mesh).	Reduced the whiteness and specific volume. French bread with 1% apple pomace (100-mesh) had highest sensory score.	He and Lu, 2015
	Addition of whole apple pomace, 5, 10, and 15% to wheat bread.	Increased in total polyphenol content, flavonoids, and anthocyanins by 55, 200 and 160% as compared to control, respectively. Reduced volume. Recorded baking loss. The bread with 5% whole pomace received the best scores (good volume, small baking loss, low crumb hardness).	Gumul et al.,2019
	Addition of apple pomace powder, 1, 2, 5, and 10%.	Increased ash, total carbohydrate, total polyphenols contents, and antioxidant activity. Decrease protein and fat contents, and loaf volume. Sensory evaluation – no significant differences in all tested attributes. The addition of 10% can be recommended.	Valková et al., 2022
Pasta/ Noodles	Replacement of durum semolina with 10 and 15% of apple peel powder.	Increased cooking loss and the amount of absorbed water. Hardness and adhesiveness have decreased. Increased total antioxidant activity and total phenolic content.	Lončarić et al.,2014

Food product	Apple pomace	Results	References
	Replacement of 10, 15, and 20% of wheat flour with apple pomace powder.	The total dietary fiber and protein content of the noodles increased from 6.0 to 13.28% and 10.20 to 11.80%, respectively, as compared to the control noodles. Increased ash content, cooking loss, swelling index, and antioxidant activity. The most acceptable product is noodles with 10% substitution.	Yadav and Gupta, 2015
	Addition of milled apple pomace, 10, 20, 30, and 50%.	Increased total polyphenols, phenolic acids, quercetin derivatives, flavon-3-ols, dihydrochalcones, dietary fiber, and minerals contents. Decreased protein and fat contents, hardness and maximum cutting energy. Water absorption capacity is not influenced up to a level of 50% apple pomace rep.	Gumul et al., 2023
Buffalo meat sausages	Replacement of 2, 4, 6, and 8% lean meat by apple pomace powder.	Increased the dietary content, cooking yield and emulsion stability, firmness, toughness, hardness, springiness, and gumminess, while the cohesiveness and chewiness decreased.	Younis and Ahmad, 2015
Chicken patties	Replacement of chicken with 10 and 20% (w/w) of wet apple pomace	Meat products with apple pomace had higher dietary fiber content (0.7–1.8 % vs. 0.1–0.2 % in control) and radical scavenging activity.	Jung et al.,2015
Beef jerky	Replacement of ground beef with 10 and 20% (w/w) of wet apple pomace		
Chicken sausages	Replacement of pork fat by incorporation of apple pomace fiber, 1 and 2%.	Lower cooking loss, total expressible fluid separation, fat separation, pH, and redness. Reduction of pork fat from 30 to 25 and 20%.	Choi et al.,2016
Beef jerky	Replacement of ground beef with 10 and 20% (w/w) of wet apple pomace	Meat products with apple pomace had higher dietary fiber content (0.7–1.8 % vs. 0.1–0.2 % in control) and radical scavenging activity.	Junget al.,2015
Buffalo meat patties	Replacement of 2, 4, 6, 8% of meat by apple pomace powder.	Increased cooking yield, emulsion stability, water holding capacity, diameter, and thickness. The texture like firmness, toughness, hardness, and cohesiveness has increased. Sensory evaluation showed acceptability up to 6% level of incorporation.	Younis and Ahmad, 2018

Food product	Apple pomace	Results	References
Fish fingers	Replacement of 2.5, 4.5, 6.5 of fish meat by apple pomace powder.	Decreased pH, crude protein, moisture, crude fat, and total ash and increased crude fiber content. Increased emulsion stability and cooking yield. Sensory evaluation showed decreasing trend.	Akhtar et al.,2019
Italian salami	Addition of dried apple pomace, 7 and 14%.	Increased fiber and phenol content, together with the lower fat and energy value.	Grispoldi et al.,2022
Beef burger	Addition of freeze-dried apple pomace, 4 and 8%.	Increased fiber and phenol content. The colour and sensory analysis of beef burger with apple pomace were graded better than the control.	Pollini et al., 2022
Yogurt	Addition of freeze-dried apple powder, 0.1, 0.5 and 1%.	Increased gelation pH and shortened fermentation time. The most stable structure over a 28-day storage period – the yogurt fortified with 0.5% apple pomace.	Wang et al., 2019
	Addition of freeze-dried apple pomace powder, 1, 2, and 3%.	Increased dietary fiber content, viscosity, firmness, and cohesiveness. Decreased whey release during cold storage.	Wang et al., 2020
	Addition of apple pomace flour, 1, 3, and 5%.	Increased total phenolic content, radical scavenging and reducing activity. The highest firmness, cohesiveness, and viscosity index values, and the highest scores for color and taste, were obtained for yogurt with 3% of apple pomace.	Jovanović et al., 2020
	Addition of apple pomace powder, 0.2–1.0%.	Reduced fermentation time. Increased total dietary fiber content and antioxidant activity. Improved the textural properties and significant reduction in syneresis during the 20 days of storage. Sensory evaluation found that that sample with 0.6–0.8% of apple pomace had the highest score.	Popescuet al., 2022

Utilization of grape processing by-products

It has been shown that by-products obtained in the processing of grapes due to their chemical composition including proteins, ash, lipids, carbohydrates, vitamins, and substances with important biological properties such as phenolic compounds, can be used as potential ingredients for enrichment of various cereal products (Boff et al., 2022). The resulting enriched bakery products are distinguished by improved nutritional characteristics, without causing significant changes in the sensory profile. However, the incorporation of by-products of grape processing requires adjustment of recipes and technological parameters to preserve the quality of baked products (García-Lomillo, 2017). Different applications of grape pomace, the main by-product of grape processing, are shown in Figure 4.

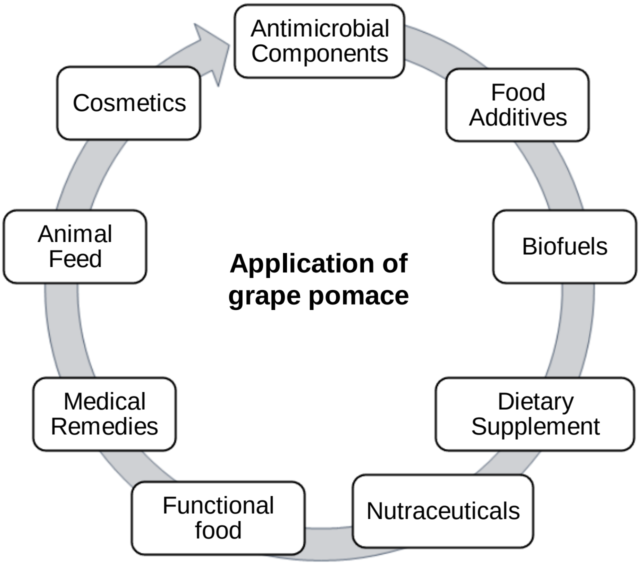


Figure 4. Application of grape pomace

Grape processing by-products can be used in the production of cereal products after drying and the formation of powder or flour, according to the relevant specifications. Thus, when using flours from grape pomace up to a maximum of 10%, cookies with a high content of phenolic compounds, antioxidants, and dietary fiber are produced, from which consumers can be satisfied (Acun et al., 2014).

Pasqualone et al. (2014) studying functional biscuits with the addition of grape pomace extract found that enriched biscuits have a strong antioxidant activity and contain a greater amount of total phenolic compounds, flavonoids, anthocyanins, and proanthocyanidins in terms of control. The intense color, fruity smell, and sour taste of enriched biscuits did not affect the product's acceptability.

Walker et al. (2014) prepared cereal products, namely bread, muffins, and brownies with 5-25% grape pomace, finding that the dietary fiber and total phenol content increased compared to the control. It has been found that enriching muffins with 20% grape by-products improve their nutritional value without showing significant changes in the sensory profile (Mildner-Szkudlarz et al., 2015). No significant changes in the sensory profile were also determined by Kuchtová et al., 2016, who replaced up to 15% composite flour in the formula for cookies, with a grape skin pomace.

In this context, Bender et al. (2017) did a study to evaluate the effects that Riesling and Tannat grape skin flour had on muffins and their taste, appearance, and texture. The inclusion of ratios 5, 7.5, and 10% of these flours affected the texture, mainly hardness, which increased as the level of addition increased, as well as the color and content of total dietary fiber. This study showed that Tannat and Riesling grape skin flour could be used as an alternative to increasing the dietary fiber content of muffins without having a negative effect on the sensory properties of the products.

In functional biscuits prepared with grape pomace powder, it was found that the addition of grape pomace does not affect the physical parameters of the cookies, but significantly affects the increase in protein and dietary fiber content. Biscuits with 4% and 6% grape pomace (w/w) tasted better, and cookies with 6% grape pomace showed higher antioxidant potency, lower anthocyanin losses, and greater hardness retention during the shelf life study (Theagarajan et al., 2019).

Nakov et al. (2020) prepared cakes by replacing wheat flour with 4%, 6%, 8 %, and 10% grape pomace powder, and it was found that as the share of pomace powder increased, the ash, fat, protein, fiber, free phenols, anthocyanins, and total polyphenol content, as well as the antioxidant capacity gradually increased, and the moisture and pH value decreased. Cakes containing 4% pomace powder had the best sensory characteristics. Studies for adding fruit by-products to different types of bread include the use of by-products ofgrape processing.

Mildner-Szkudlarz et al. (2011) developed a new formulation for mixed rye bread produced with grape pomace as an alternative source of dietary fiber, ash and dietary polyphenols. New formulations have been shown to have a significantly higher total dietary fiber content and have been characterized by significantly higher antioxidant activity associated with their phenolic compound content.

According to a study conducted by Hayta et al. (2014), incorporating about 5% (w/w, flour basis) grape pomace powder into bread formulation positively affects the total phenol content and anti-radical activity. It has been found that the addition of grape trop powder contributes to the bread to improve its functional properties.

Tolve et al. (2021) prepared wheat bread in which a portion of wheat flour, 5, and 10 g/100 g have been replaced by grape pomace powder. The inclusion of a higher level of grape pomace powder caused a decrease in the total starch content (from 85.5 to 75.3 g/100 g DM) and an increase in the total dietary fiber content (2.8 to 6.3 g/100 g DM). As the proportion of pomace in bread increased, total phenolic compounds and antioxidant capacity increased. The total phenolic compounds increased 3.5-fold and 7-fold as GPP replacement increased from 0% to 5% and from 0% to 10%, respectively. The grape pomace powder addition did not have a significant impact on the overall acceptability of the product.

Rainero et al. (2022), in their study with breadsticks, replaced wheat flour with 5 and 10 g 100 g^{-1} of powdered grape pomace, and they observed that the total phenolic compounds, dietary fiber, and antioxidant capacity increased. The content of total phenolic compounds increased from 72.21 to 171.83 mg GAE 100 g^{-1} DM, the dietary fiber from 3.47 to 5.81 and 8.55 g 100 g^{-1} DM and antioxidant capacity evaluated by FRAP (ferric reducing ability of plasma) increased from 360.60 to 2801.00 μM TE 100 g^{-1} DM. Breadsticks with 5 g 100 g^{-1} of powdered grape pomace flour showed lower overall acceptability.

When foods are enriched with fiber, it is necessary to evaluate the effects that added fiber has on consumers' perceptions of color, texture, and acceptability. For example, the baking properties of some products can be significantly affected when a portion of wheat flour is replaced by ingredients that are rich in fiber. Such effects include a decrease in the volume or height of the bread and changes in texture (increases the hardness of the crumb, loss of crunchiness), appearance (surface properties, color, density), and intensity of smell and taste (Bender et al., 2017; Šporin et al., 2018). Sensory assessment of bread with added pomace suggests that a maximum of 6% grape pomace can be incorporated to prepare acceptable products (Mildner-Szkudlarz et al., 2011).

Smith et al. (2015) used grape pomace of four grape varieties to substitute 5 and 10% flour in a white bread formulation. The results showed that bread with 5% grape pomace has a similar volume of bread, but a darker color compared to the control, while bread with 10% grape pomace became denser. Dietary fiber, polyphenols, and antioxidant activity of bread increased with increasing content of grape pomace in the formulation. Grapes can also be used in the production of pasta. Choosing this by-product as a functional ingredient for pasta production can improve the nutritional profile of this widely consumed food, increase the daily intake of phenols and fiber, and add economic value to wine production (Balli et al., 2021).

Namely, Tolve et al. (2020) performed enrichment of pasta by replacing 5 and 10 % of semolina with grape pomace. By incorporating grape pomace in pasta optimal cooking time and the swelling index were significantly reduced, the firmness and adhesiveness of the pasta were improved, the total phenolic content and antioxidant activity increased, and sensory analysis showed that enriched spaghetti had good overall acceptability.

Balli et al. (2021) conducted a study in order to assess the possibility of using dry grape pomace as a source of phenolic compounds and fibers in tagliatelle pasta, which are usually characterized by a negligible amount of phenolic compounds and fibers. The profile of pasta enriched with 7% dry grape pomace was studied, focusing on phenolic compounds after cooking. The enriched tagliatelle was characterized by improved organoleptic and nutritional characteristics, retained phenolic compounds after cooking, and an increased amount of fiber. The enriched tagliatelle retained the same monoglycolized and acetylated anthocyanins found in grapes. In enriched tagliatelle, the fiber content increased by ≈ 3%, while the added phenols retained after cooking the enriched tagliatelle amounted to 6.21 mg/100 g.

Grape by-products have been added to various dairy products (Antonić et al., 2020), such as yogurt, kefir, cheese, and salad dressing. Some studies have shown that the effectiveness is lower than in cereal products due to instability and loss of nutritional components in the processing and storage of dairy products, as well as other technological problems (García-Lomillo et al., 2017).

In addition, several studies have reported the use of grape pomace in meat products such as chicken nuggets and chevon nuggets. The summary of the various studies on application of grape by-products in food product preparation is presented in Table 2.

Table 2

Application of grape by-products in food product preparation

Product	**Grape by-products**	Results	References
Biscuits	Addition of white grape pomace powder, 10, 20 and 30% (w/w)	Increased total dietary fiber from 0.85 mg GAE g^{-1} DM to 4.45 mg GAE g^{-1} DM, total phenolic compound content from 0.11 mg g^{-1} DM to 1.07 mg g^{-1} DM, and significantly higher antioxidant activities. Sensory profile analysis showed acceptability up to 10% level of incorporation.	Mildner-Szkudlarz et al., 2013

Product	**Grape by-products**	Results	References
	Adding grape seed powder, 5, 10, 15 and, 20% of the weight of flour	Adding grape seed powder to wheat flour lowers the output gluten reduces its sensibility and increases elasticity. Adding 15.0 % of grape seed powder to butter biscuits improves their physicochemical (specific volume and wetting ability) as well as organoleptic quality indices.	Samohvalova et al., 2016
	Replacing cocoa powder with grape pomace powder in ratios of 50 and 100%.	The grape powder does not significantly affect the height, spread ratio, hardness, flexibility, toughness, appearance, and odor of biscuits. A positive impact on biscuits flavor, despite fruity taste.	Molnar et al., 2020
	Wheat flour substitution by Tannat grape pomace flour, 10 and 20% (w/w) in the total wet biscuit mass.	Increased the content of total polyphenols and antioxidant capacity. Greater α-glucosidase and pancreatic lipase inhibition capacity compared to the biscuits without grape pomace flour.	Olt et al., 2022
Cookies	Addition of whole grape pomace flour and pomace flour without seeds at levels of 5, 10, and 15%, and seed flour at levels of 5, 7.5, and 10%.	Not significantly affected on the width, thickness, and spread ratio of cookies. Total dietary fiber and total phenolics increased as compared to the control. Cookies with 10% seed flour had higher total dietary fiber and total phenolics (153.10 g/kg GAE and 5.61 mg/mL, respectively) than others. The best acceptable product is cookies with 5% seed flour.	Acun and Gü, 2014
	Replacing wheat flour with wine grape pomace powder at levels of 5, 10, 15, and 20 %.	Increased colour intensity, antioxidant properties, total phenol content, flavonoid, and anthocyanin. Samples with 5 % of wine grape pomace powder had the maximum score.	Maner et al., 2017
	Replacing wheat flour with grape pomace powder at levels of 2.5, 5.0, 7.5, and 10.0 % with 3 different granulations (0.25, 0.50, 1.00 mm)	Well accepted due to their good appearance, likable colour, pleasant aroma, and taste. Those that contain grape pomace powder in granulation 1.00 mm are the best.	Temkov et al., 2021
Muffins	Replacing whole-wheat flour with white and red grape pomace at levels of 10 and 20%	The high content of fiber. Decreased elasticity, cohesion, resilience, and color parameters of the muffins with white and red grape pomace. Increased chewiness and firmness. High levels of acceptability of the muffins that incorporated white and red grape pomace products at concentrations of 10%.	Ortega-Heras et al., 2019

Product	**Grape by-products**	Results	References
	Replacing rice flour with grape pomace powder at levels of 15, and 25%.	Improved nutritional composition of the gluten-free muffins. Increased protein from 5.00 g/100 g dwb to 5.72 g/100 g dwb and 6.64 g/100 g dwb, crude fiber content from 0.05 g/100 g dwb to 1.47 g/100 g dwb and 2.19 g/100 g dwb. Good level of acceptability.	Baldánet al., 2021
	Addition of 7.5% and 15% grape seed flour substituting whole wheat, whole siyez wheat, and whole oat flour.	Increased protein, lipid, moisture, phenolic contents, and antioxidant capacity with an increased amount of grape seed flour addition. Decreased hardness and chewiness of the muffins with whole wheat flour and whole siyez wheat flour, and increased of the muffins with whole oat flour.	Yalcin et al., 2021
	Addition of 15% grape pomace powder with different particle size fractions (600-425, 425-300, 300-212 and 212-150 µm)	Thinner granulometry -higher values of antioxidant activity, anthocyanin, and phenol content. From a textural and sensorial point of view, the smaller particle sizes negatively affected the hardness and color in terms of lightness, as well as the homogeneity of the pores.	Troilo et al., 2022
Bread	Addition of 'Merlot' and 'Zelen'grape pomace flour, 6, 10, and 15%.	Positive correlation with phenolic content and antioxidant activity, and negative correlation with brightness and firmness. The variety 'Zelen' is suggested for use.	Šporin et al., 2018
	Replacement of wheat flour with 1%, 2%, 5%, and 8% (w/w) of grape seeds micropowder (GSMP) with nanosized particles (10 µm).	Positive effect on dough manifesting with rheology by increased dough stability. Significantly decreased bread volume was observed in the bread supplemented with ≥ 2%. The bread supplemented with 1% had the highest scores for all the quality attributes.	Valková et al., 2020
	Replacement of wheat flour with 3%, 5%, 7%, and 9% (w/w) of grape seeds flour.	Increased fiber, protein, and minerals. Declined rheological parameters and technological performance. The samples with 3% and 5% can be considered a fiber source and Cu source, respectively, and are rich in Zn. The samples containing 7% and 9% – unsatisfactory from rheological and sensorial points of view.	Oprea et al., 2022
Panettones	Incorporation of powdered compound produced from grape bark and arrowroot in the proportions of 10%, 15%, and 20% (m/m) in place of wheat flour.	Not differ statistically from the traditional formulation in terms of moisture content, lipids, proteins, and water activity. Increased color intensity, flavonoids (1.58 mg QE g^{-1}; 1.71 mg QE g^{-1}; 1.83mg QE g^{-1}), and anthocyanins content (1.20 $mg.g^{-1}$; 1.34$mg.g^{-1}$; 1.41 $mg.g^{-1}$) in contrast to traditional panettone (0.03 for both).	Souza et al., 2023

Product	**Grape by-products**	Results	References
Pasta / Spaghetti	Incorporation of 25, 50 and 75 g/kg of grape marc powder.	Increased total phenolic content, condensed tannins, monomeric anthocyanin and compounds antioxidant capacity. The sensory analysis found that the incorporation reduced the acceptance of aroma, aftertaste, flavor, and appearance. The best overall acceptance, with lower changes of color is fettuccini pasta with 25 g/kg incorporation.	Sant'Anna et al., 2014
	Replacement of wheat flour in proportions of 3, 6 and 9% (w/w) with grape pomace skins.	Improvements in the polyphenolic content. Increased antioxidant capacity. Improved sensory and functional properties up to a level of 6%.	Gaita et al., 2020
	Grape marc extracts (grape marc suspended in water at a ratio of 1: 10 (w/v)).	Higher content of phenolic compounds, flavonoids, and antioxidant activity. No difference in optimum cooking time (around 10 min.). Low cooking losses. Without altering sensory characteristics..	Marinelli et al., 2015
	Addition of 15% (w/w) red grape marc flour with a different particle size (500 µm; 125µm) to durum wheat semolina.	Increased total polyphenol, anthocyanin content, and antioxidant activity. Decreased bioaccessible glucose.	Marinelli et al., 2018
"Vegan" sausages	Addition of the grape seed flour with different concentra-tions 0,1,3,7,10,20%.	Increased antioxidant capacity and polyphenol content. Decreased protein. The most acceptable product is vegan sausages with 1% and 3% addition.	Tremlova et al., 2022
Chicken nuggets	Replacement of flour mix (wheat flour, corn flour, leavening agent, salt) with grape seed flour amounts of 1, 2, 5, 8, and 10%.	Higher antioxidant activity. Reduced lipid oxidation. Decreased thiobarbituric acid reactive substance, para-anisidine values, and conjugated diene concentration values.	Cagdas and Kumcuoglu, 2015
Chevon nuggets	Addition of grape seed extract, 5% stock solution (0.5g of dried extract /10 mL).	Lower thiobarbituric acid reactive substance and free fatty acid, %. Reduced total plate, total psychrophilic, and yeast and mold count. A superior score of flavor, juiciness, and overall acceptability.	Meena et al., 2021
Semi-hard and hard cheeses	Added grape pomace powder (Barbera, Chardonnay before distillation, Chardonnay after distillation)/ at two concentration levels 0.8 and 1.6 % (w/w).	Higher antioxidant activity and phenolic content in all fortified cheeses, but to obtain a significant increase in cheese antioxidant activity it is necessary to add at least 1.6 % of grape pomace powder. The highest total phenolic content and radical scavenging activity values at the end of ripening (30 days and 120 days respectively) showed cheeses fortified with Chardonnay after distillation powder.	Marchiani et al., 2015

Product	**Grape by-products**	Results	References
Spreadable cheese	Addition of white and red grape pomace powders at a concentration of 5% (w/w).	Increased total phenolic content (2.74 ± 0.04 and 2.34 ± 0.15 mg GAEs/g dw, respectively) compared to the control (0.66 mg GAEs/g dw). Increased flavonoids, and antioxidant activity. Decrease of pH.	Luceraet al., 2018
Fresh ovine “primosale” cheese	Addition of 1% (w/w) grape pomace powder with four selected Lactococcus lactis strains.	Reduced fat content and increased protein and secondary lipid oxidation. Increased antioxidant activity of the cheese after that the dairy matrix was degraded by the simulated digestive process.	Gaglio et al., 2021
Ovine Vastedda-like stretched cheese	Incorporation of 1% (w/w) red grape pomace powder Nero d’Avola Cultivar into ovine stretched cheese.	Higher protein, polyphenols content, and lower fat content. Favorable influence on sensory traits.	Barbaccia et al., 2022
Kefir	Addition of Sangiovese skins and seeds extracts at a concentration of 1, 5, and 10 mg.	Better antioxidant activity. Good performance in the inhibition of key enzymes linked to metabolic syndrome (α-amylase, α-glucosidase, and lipase).	Carullo et al., 2020
Yogurt, Italian and Thousand Island salad dressing	Addition of 1%, 2%, and 3% (w/w yogurt) grape pomace powder; 0.5 and 1% grape pomace powder (w/w Italian salad dressing); 1 and 2% grape pomace powder (w/w Thousand Island salad dressing).	Higher dietary fiber content. Decreased total phenolic content and DPPH radical scavenging activity during storage. Best received products are 1% (w/w) fortified yogurt, 0.5% (w/w) fortified Italian dressing, and 1% (w/w) fortified Thousand Island dressing.	Tseng et al., 2013
Yogurt	Addition of grape skin flours (Chardonnay, Moscato, and Pinot noir varieties) in a proportion of 60 g/kg in yogurt.	Yogurt containing grape skin flour presented significantly higher total phenolic content (+55%), antioxidant activity (+80%), and acidity (+25%) whereas lower pH, syneresis (−10%), and fat (−20%) than control. Retained total phenolic content and radical scavenging activity during yogurt storage (no significant changes observed).	Marchiani et al., 2016
	Addition of Tannat grape skin powder in a proportion of 0.5% (w/w) in yogurt.	Increased α-glucosidase inhibition capacity. The antioxidant capacity increased slightly with time until day 12 and then remained unchanged up to the end of the study (28 days). Higher overall acceptance.	Fernández-Fernández et al., 2022

Conclusion

The utilization of waste from the fruit processing industry to be used for preparation of new food products is an innovative and functional way for environmental protection. In addition to reducing environmental pollution, functional food products with better nutritional characteristics are created. It has been proven that waste from apple and grape processing contains biologically active substances such as polyphenols, dietary fibers, proteins, fats, minerals, has antioxidant, antimicrobial, anti-carcinogenic, antiviral and antibacterial characteristics and can be successfully incorporated into new functional food products.

References

Acun S., Gü H. (2014), Effects of grape pomace and grape seed flours on cookie quality, *Quality Assurance and Safety of Crops & Foods*, 6(1), pp. 81–88, DOI: 10.3920/QAS2013.0264

Akhtar S., Gani M., Hakeem H.R., Ganie S. A., Mir M.A., Dar A. H. (2019), Effect of apple pomace powder on the quality attributes of fish fingers, *Journal of Fisheries Research*, 3(1), pp. 26-34, DOI: 10.35841/fisheries-research.3.1.26-34

Alongi M., Melchior S., Anese M. (2019), Reducing the glycemic index of short dough biscuits by using apple pomace as a functional ingredient, *LWT*, 100, pp. 300–305, DOI: 10.1016/j.lwt.2018.10.068

Antonić B., Jančíková S., Dordević D., Tremlová B. (2020), Grape pomace valorization: a systematic review and meta-analysis, *Foods*, 9(11), 1627, DOI: 10.3390/foods9111627

Baldán Y., Riveros M., Fabani M.P., Rodriguez R. (2021), Grape pomace powder valorization: a novel ingredient to improve the nutritional quality of gluten-free muffins, *Biomass Conversion and Biorefinery*, DOI: 10.1007/s13399-021-01829-8

Balli D., Cecchi L., Innocenti M., Bellumori M., Mulinacci N. (2021), Food by-products valorisation: grape pomace and olive pomace (pâté) as sources of phenolic compounds and fiber for enrichment of tagliatelle pasta, *Food Chemistry*, 355, 129642, DOI: 10.1016/j.foodchem.2021.129642

Barbaccia P., Busetta G., Barbera M., Alfonzo A., Garofalo G., Francesca N., Moscarelli A., Moschetti G., Settanni L., Gaglio R. (2022), Effect of grape pomace from red cultivar 'Nero d'Avola' on the microbiological, physicochemical, phenolic profile and sensory aspects of ovine Vastedda-like stretched cheese, *Journal of Applied Microbiology*, 133(1), pp. 130–144, DOI: 10.1111/jam.15354

Bchir B., Karoui R., Danthine S., Blecker C., Besbes S., Attia H. (2022), Date, apple, and pear by-products as functional ingredients in pasta: cooking quality attributes and physicochemical, rheological, and sensorial properties, *Foods*, 11(10), 1393, DOI: 10.3390/foods11101393

Bender B. B. A., Speroni S. C., Salvador R. P., Loureiro B. B., Lovatto M. N., Goulart R.F., Lovatto T. M., Miranda Z. M., Silva P. L., Penna G .N. (2017), Grape pomace skins and the effects of its inclusion in the technological properties of muffins, *Journal of Culinary Science & Technology*, 15(2), pp. 143–157, DOI: 10.1080/15428052.2016.1225535

Boff J. M., Strasburg V. J., Ferrari G. T., de Oliveira Schmidt H., Manfroi V., de Oliveira V. R. (2022), Chemical, technological, and sensory quality of pasta and bakery products made with the addition of grape pomace flour, *Foods*, 11, pp. 3812, DOI: 10.3390/ foods11233812

Bora P., Ragaee S., Abdel-Aal E.-S. M. (2019), Effect of incorporation of goji berry by-product on biochemical, physical and sensory properties of selected bakery products, *LWT*, 112, 108225, DOI: 10.1016/j.lwt.2019.05.123

Cagdas E., Kumcuoglu S. (2015), Effect of grape seed powder on oxidative stability of precooked chicken nuggets during frozen storage, *Journal of Food Science and Technology,* 52(5), pp. 2918–2925, DOI: 10.1007/s13197-014-1333-7

Carullo G., Spizzirri U.G., Loizzo M.R., Leporini M., Sicari V., Aiello F., Restuccia D. (2020), Valorization of red grape (*Vitis vinifera cv. Sangiovese*) pomace as functional food ingredient, *Italian Journal of Food Science,* 32, pp. 367–385, DOI: 10.14674/IJFS-1758

Castro L. A., Lizi J.M., Chagas E.G.L.D., Carvalho R.A., Vanin F.M. (2020), From orange juice by-product in the food industry to a functional ingredient: application in the circular economy, *Foods,* 9(5), 593, DOI: 10.3390/foods9050593

Choi Y.S., Kim Y.B., Hwang K.E., Song D.H., Ham Y.K., Kim H.W., Sung J.M., Kim C.J. (2016), Effect of apple pomace fiber and pork fat levels on quality characteristics of uncured, reduced-fat chicken sausages, *Poultry Science,* 95(6), pp. 1465–1471, DOI: 10.3382/ps/pew096

Colantuono A. (2019), Vegetable by-products as a resource for the development of functional foods, In: Ferranti P., Berry E. M., Anderson J. R. (eds.), *Encyclopedia of Food Security and Sustainability,* Elsevier, pp. 360–363, DOI: 10.1016/b978-0-08-100596-5.22142-2

Dhillon G. S., Kaur S., Brar S. K. (2013), Perspective of apple processing wastes as low-cost substrates for bioproduction of high value products: A review, *Renewable and Sustainable Energy Reviews,* 27, pp. 789–805, DOI: 10.1016/j.rser.2013.06.046

Djeghim F., Bourekoua H., Różyło R., Bieńczak A., Tanaś W., Zidoune M.N. (2021), Effect of by-products from selected fruits and vegetables on gluten-free dough rheology and bread properties, *Applied Sciences,* 11(10), pp. 4605, DOI: 10.3390/app11104605

Erinle T. J., Adewole D. I. (2022), Fruit pomaces - their nutrient and bioactive components, effects on growth and health of poultry species, and possible optimization techniques, *Animal Nutrition*, 9, pp. 357–377, DOI: 10.1016/j.aninu.2021.11.011

Fernández-Fernández A. M., Dellacassa E., Nardin T., Larcher R., Ibañez C., Terán D., Gámbaro A., Medrano-Fernandez A., del Castillo M.D. (2022), Tannat grape skin: A feasible ingredient for the formulation of snacks with potential for reducing the risk of diabetes, *Nutrients*, 14(3), pp. 419, DOI: 10.3390/nu14030419

Fierascu R. C., Sieniawska E., Ortan A., Fierascu I., Xiao J. (2020), Fruits by-products – a source of valuable active principles. A short review, *Frontiers in Bioengineering and Biotechnology,* 8, 319, DOI: 10.3389/fbioe.2020.00319

Gaglio R., Barbaccia P., Barbera M., Restivo I., Attanzio A., Maniaci G., Di Grigoli A., Francesca N., Tesoriere L., Bonanno A., Moschetti G., Settanni L. (2021), The use of winery by-products to enhance the functional aspects of the fresh ovine "primosale" cheese, *Foods,* 10(2), 461, DOI: 10.3390/foods10020461

Gaita C., Alexa E., Moigradean D., Conforti F., Poiana M. A. (2020), Designing of high value-added pasta formulas by incorporation of grape pomace skins, *Romanian Biotechnological Letters*, 25(3), pp. 1607–1614, DOI: 10.25083/rbl/25.3/1607.1614

Galanakis C. M. (2012), Recovery of high added-value components from food wastes: Conventional, emerging technologies and commercialized applications, *Trends in Food Science & Technology*, 26(2), pp. 68–87, DOI: 10.1016/j.tifs.2012.03.003

García-Lomillo J., González-SanJosé M. L. (2017), Applications of wine pomace in the food industry: Approaches and functions, *Comprehensive Reviews in Food Science and Food Safety,* 16(1), pp. 3–22, DOI: 10.1111/1541-4337.12238

Grispoldi L., Ianni F., Blasi F., Pollini L., Crotti S., Cruciani D., Cenci-Goga B. T., Cossignani L. (2022), Apple pomace as valuable food ingredient for enhancing nutritional and antioxidant properties of Italian salami, *Antioxidants,* 11(7), pp. 1221, DOI: 10.3390/antiox11071221

Gumul D., Korus J., Ziobro R., Kruczek M. (2019), Enrichment of wheat bread with apple pomace as a way to increase pro-health constituents, *Quality Assurance and Safety of Crops & Foods*, 11(3), pp. 231–240, DOI: 10.3920/QAS2018.1374

Gumul D., Kruczek M., Ivanišová E., Słupski J., Kowalski S. (2023),Apple pomace as an ingredient enriching wheat pasta with health-promoting compounds, *Foods,* 12, pp. 804, DOI: 10.3390/foods12040804

Hayta M., Özuğur G., Etgü H., Şeker T. İ. (2014), Effect of grape (*Vitis vinifera* L.) pomace on the quality, total phenolic content and anti-radical activity of bread, *Journal of Food Processing and Preservation,* 38(3), pp. 980–986, DOI: 10.1111/jfpp.12054

He Y.Q., Lu Q. (2015), Impact of apple pomace on the property of French bread, *Advance Journal of Food Science and Technology,* 8, pp. 167–172, DOI: 10.19026/ajfst.8.1487

Ivanov V., Shevchenko O., Marynin A., Stabnikov V., Gubenia O., Stabnikova O., Shevchenko A., Gavva O., Saliuk A. Trends and expected benefits of the breaking edge food technologies in 2021–2030,*Ukrainian Food Journal,* 2021, 10(1), pp. 7-36, DOI: 10.24263/2304-974X-2021-10-1-3

Jannati N., Hojjatoleslamy Z, M., Hosseini E., Mozafari H.R., Siavoshi M. (2018), Effect of apple pomace powder on rheological properties of dough and sangak bread texture, *Carpathian Journal of Food Science and Technology*, 10(2), pp. 77–84.

Jovanović M., Petrović M., Miočinović J., Zlatanović S., Laličić Petronijević J., Mitić-Ćulafić D., Gorjanović S. (2020), Bioactivity and sensory properties of probiotic yogurt fortified with apple pomace flour, *Foods,* 9(6), 763, DOI: 10.3390/foods10081696

Jung J., Cavender G., Zhao Y. (2015), Impingement drying for preparing dried apple pomace flour and its fortification in bakery and meat products, *Journal of Food Science and Technology,* 52(9), pp. 5568–5578, DOI: 10.1007/s13197-014-1680-4

Karkle E. L., Alavi S., Dogan H. (2012), Cellular architecture and its relationship with mechanical properties in expanded extrudates containing apple pomace, *Food Research International*, 46(1), pp. 10–21, DOI: 10.1016/j.foodres.2011.11.003

Kırbaş Z., Kumcuoglu S., Tavman S. (2019), Effects of apple, orange and carrot pomace powders on gluten-free batter rheology and cake properties, *Journal of Food Science & Technology*, 56(2), pp. 914–926, DOI: 10.1007/s13197-018-03554-z

Kuchtová V., Karovičová J., Kohajdová Z., Minarovičová L., Kimličková V. (2016), Effects of white grape preparation on sensory quality of cookies, *Acta Chimica Slovaca,* 9(2), pp. 84–88, DOI:10.1515/acs-2016-0014

Larrosa Q. P., Otero M. D. (2021), Flour made from fruit by-products: characteristics, processing conditions, and applications, *Journal of Food Processing and Preservation*, 00, 15398, DOI:10.1111/jfpp.15398

Lau K. Q., Sabran M. R., Shafie S. R. (2021), Utilization of vegetable and fruit by-products as functional ingredient and food, *Frontiers in Nutrition,* 8, pp. 661693, DOI: 10.3389/fnut.2021.661693

Lauková M., Kohajdová Z., Karovičová J. (2016), Effect of hydrated apple powder on dough rheology and cookies quality, *Potravinarstvo*, 10(1), pp. 506–511, DOI: 10.5219/597

León E. A. V., Aldapa C. A. G., Rojas J. A., Torres A. V., Uribe J. P. H., Rodríguez H. M. P., Cortez R. O. N. (2022), Phytochemical content and antioxidant activity of extruded products made from yellow corn supplemented with apple pomace powder, *Food Science and Technology*, 42, pp. 91221, DOI: 10.1590/fst.91221

Leyva-López N., Lizárraga-Velázquez C.E., Hernández C., Sánchez-Gutiérrez E. Y. (2020), Exploitation of agro-industrial waste as potential source of bioactive compounds for aquaculture, *Foods,* 9, pp. 843, DOI: 10.3390/foods9070843

Lončarić A., Kosović I., Jukić M., Ugarčić Ž., Piližota V. (2014), Effect of apple by-product as a supplement on antioxidant activity and quality parameters of pasta, *Croatian Journal of Food Science and Technology*, 6, pp. 97–103, DOI: 10.17508/CJFST.2014.6.2.05

Lucera A., Costa C., Marinelli V., Saccotelli M. A., Del Nobile M. A., Conte A. (2018), Fruit and vegetable by-products to fortify spreadable cheese, *Antioxidants*, 7(5), pp. 61, DOI: 10.3390/antiox7050061

Lyu F., Luiz S. F., Azeredo D. R. P., Cruz A. G., Ajlouni S., Ranadheera C. S. (2020), Apple pomace as a functional and healthy ingredient in food products: a review, *Processes,* 8, pp. 319, DOI: 10.3390/pr8030319

Majerska J., Michalska A., Figiel A. (2019), A review of new directions in managing fruit and vegetable processing by-products, *Trends in Food Science & Technology*, 88, pp. 207–219, DOI: 10.1016/j.tifs.2019.03.021

Maner S., Sharma A.K., Banerjee K. (2017), Wheat flour replacement by wine grape pomace powder positively affects physical, functional and sensory properties of cookies, *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences,* 87, pp. 109–113, DOI: 10.1007/s40011-015-0570-5

Marchiani R., Bertolino M., Belviso S., Giordano M., Ghirardello D., Torri L., Piochi M., Zeppa G. (2016), Yogurt enrichment with grape pomace: effect of grape cultivar on physicochemical, microbiological and sensory properties, *Journal of Food Quality,* 39, pp. 77–89, DOI: 10.1111/jfq.12181

Marchiani R., Bertolino M., Ghirardello D., McSweeney P. L. H., Zeppa G. (2015). Physicochemical and nutritional qualities of grape pomace powder-fortified semi-hard cheeses, *Journal of Food Science and Technology,* 53, pp. 1585–1596, DOI: 10.1007/s13197-015-2105-8

Marinelli V., Padalino L., Conte A., Del Nobile M. A., Briviba K. (2018), Red grape marc flour as food ingredient in durum wheat spaghetti: nutritional evaluation and bioaccessibility of bioactive compounds, *Food Science and Technology Research*, 24 (6), pp. 1093–1100, DOI: 10.3136/fstr.24.1093

Marinelli V., Padalino L., Nardiello D., Del Nobile M. A., Conte A. (2015), New approach to enrich pasta with polyphenols from grape marc, *Journal of Chemistry*, 2015: 734578, DOI: 10.1155/2015/734578

Meena P., Pandey A., Saini A., Gurjar A.S., Raman R., Meel S.K., Chauhan V.K. (2021), Effect of grape (*Vitis vinifera*) seed extract on the physico-chemical, microbial and sensory characteristics of chevon nuggets, *Indian Journal of Animal Research*, 55(3), pp. 364–368, DOI: 10.18805/ijar.B-3958

Mildner-Szkudlarz S., Bajerska J., Zawirska-Wojtasiak R., Górecka D. (2013), White grape pomace as a source of dietary fibre and polyphenols and its effect on physical and nutraceutical characteristics of wheat biscuits, *Journal of the Science of Food and Agriculture*, 93(2), pp. 389–395, DOI: 10.1002/jsfa.5774

Mildner-Szkudlarz S., Siger A., Szwengiel A., Bajerska J. (2015), Natural compounds from grape by-products enhance nutritive value and reduce formation of CML in model muffins, *Food Chemistry*, 172, pp. 78–85, DOI: 10.1016/j.foodchem.2014.09.036

Mildner-Szkudlarz S., Zawirska-Wojtasiak R., Szwengiel A., Pacyński M. (2011), Use of grape by-product as a source of dietary fibre and phenolic compounds in sourdough mixed rye bread, *International Journal of Food Science and Technology*, 46, pp. 1485–1493, DOI: 10.1111/j.1365-2621.2011.02643.x

Mir S. A., Bosco S. J. D., Shah M. A., Santhalakshmy S., Mir M. M. (2017), Effect of apple pomace on quality characteristics of brown rice based cracker, *Journal of the Saudi Society of Agricultural Sciences,* 16(1), pp. 25–32, DOI: 10.1016/j.jssas.2015.01.001

Molnar D., Novotni D., Krisch J., Bosiljkov T., Ščetar M. (2020), The optimisation of biscuit formulation with grape and aronia pomace powders as cocoa substitutes, *Croatian Journal of Food Technology, Biotechnology and Nutrition*, 15, pp. 38–44, DOI: 10.31895/hcptbn.15.1-2.5

Nakov G., Andrea B., Hidalgo A., Ivanova N., Stamatovska V., Dimov I. (2020), Effect of grape pomace powder addition on chemical, nutritional and technological properties of cakes, *LWT – Food Science and Technology,* 134, 109950, DOI: 10.1016/j.lwt.2020.109950

Nakov G., Brandolini A., Hidalgo A., Ivanova N., Jukić M., Komlenić D. K., Lukinac J. (2020), Influence of apple peel powder addition on the physico-chemical characteristics and nutritional quality of bread wheat cookies, *Food Science and Technology International*, 26(7), pp. 574–582, DOI: 10.1177/1082013220917282

Olt V., Báez J., Curbelo R., Boido E., Dellacassa E., Fernández-Fernández A.M., Medrano A. (2022), Development of potential functional biscuits with the incorporation of tannat grape pomace and sweetener, *Biology and Life Sciences Forum*, 18(1), pp. 50, DOI: 10.3390/Foods2022-13067

Oprea O.B., Popa M.E., Apostol L., Gaceu L. (2022), Research on the potential use of grape seed flour in the bakery industry, *Foods*, 11, 1589, DOI: 10.3390/foods11111589

Ortega-Heras M., Gómez I., de Pablos-Alcalde S., González-Sanjosé M. L. (2019), Application of the just-about-right scales in the development of new healthy whole-wheat muffins by the addition of a product obtained from white and red grape pomace, *Foods*, 8(9), 419, DOI: 10.3390/foods8090419

Pasqualone A., Bianco A.M., Paradiso V.M., Summo C., Gambacorta G., Caponio F. (2014), Physico-chemical, sensory and volatile profiles of biscuits enriched with grape marc extract, *Food Research International*, 65, pp. 385–393, DOI: 10.1016/j.foodres.2014.07.014

Piasecka I., Górska A. (2020), Possible uses of fruit pomaces in food technology as a fortifying additive – a review, *Zeszyty Problemowe Postępów Nauk Rolniczych*, 600, pp. 43–54, DOI: 10.22630/ZPPNR.2020.600.5

Pollini L., Blasi F., Ianni F., Grispoldi L., Moretti S., Di Veroli A., Cossignani L., Cenci-Goga B. T. (2022), Ultrasound-assisted extraction and characterization of polyphenols from apple pomace, functional ingredients for beef burger fortification, *Molecules*, 27(6), 1933, DOI: 10.3390/molecules27061933

Popescu L., Ceșco T., Gurev A., Ghendov-Mosanu A., Sturza R., Tarna R. (2022), Impact of apple pomace powder on the bioactivity, and the sensory and textural characteristics of yogurt, *Foods,* 11(22), 3565, DOI: 10.3390/foods11223565

Rainero G., Bianchi F., Rizzi C., Cervini M., Giuberti G., Simonato B. (2022), Breadstick fortification with red grape pomace: effect on nutritional, technological and sensory properties, *Journal of the Science of Food and Agriculture,* 102(6), pp. 2545–2552, DOI: 10.1002/jsfa.11596

Reis S.F., Rai D.K., Abu-Ghannam N. (2014), Apple pomace as a potential ingredient for the development of new functional foods, *International Journal of Food Science,* 49(7), pp. 1743–1750, DOI: 10.1111/ijfs.12477

Rupasinghe V. H. P., Wang L., Huber M. G. Pitts L. N. (2008), Effect of baking on dietary fibre and phenolics of muffins incorporated with apple skin powder, *Food Chemistry,* 107, pp. 1217–1224, DOI: 10.1016/j.foodchem.2007.09.057

Rupasinghe V. H. P., Wang L., Pitts L. N., Astatkie T. (2009), Baking and sensory characteristics of muffins incorporated with apple skin powder, *Journal of Food Quality*, 32, pp. 685–694, DOI: 10.1111/j.1745-4557.2009.00275.x

Samohvalova O., Grevtseva N., Brykova T., Grigorenko A. (2016), The effect of grape seed powder on the quality of butter biscuits, *Eastern-European Journal of Enterprise Technologies*, 3(11), pp. 61–66, DOI: 10.15587/1729-4061.2016.69838

Sant'Anna V., Christiano F.D.P., Marczak L.D.F., Tessaro I.C., Thys R.C.S. (2014), The effect of the incorporation of grape marc powder in fettuccini pasta properties, *LWT – Food Science and Technology*, 58, pp. 497–501, DOI: 10.1016/j.lwt.2014.04.008

Singha P., Muthukumarappan K. (2018), Single screw extrusion of apple pomace-enriched blends: Extrudate characteristics and determination of optimum processing conditions, *Food Science and Technology International*, 24(5), pp. 447–462, DOI: 10.1177/1082013218766981

Smith I. N., Yu J. (2015), Nutritional and sensory quality of bread containing different quantities of grape pomace from different grape cultivars, *EC Nutrition*, 2, pp. 291–301.

Souza E.L., Santos L.F.P., Barreto G. de A., Leal I.L., Oliveira F.O., dos Santos L. M. C., Ribeiro C. D. F., Rezende C. S. M., Machado B.A.S. (2023), Development and characterization of panettones enriched with bioactive compound powder produced from Shiraz grape by-product (*Vitis vinifera* L.) and arrowroot starch (*Maranta arundinaceae* L.), *Food Chemistry Advances*, 100220, DOI: 10.1016/j.focha.2023.100220

Spinei M., Oroian M. (2021), The potential of grape pomace varieties as a dietary source of pectic substances, *Foods*, 10, pp. 867, https://doi.org/10.3390/foods 10040867

Šporin M., Avbelj M., Kovač B., Možina S. S. (2018), Quality characteristics of wheat flour dough and bread containing grape pomace flour, *Food Science and Technology International*, 24(3), pp. 251–263, DOI: 10.1177/1082013217745398

Stabnikova O., Marinin A., Stabnikov V. (2021), Main trends in application of novel natural additives for food production, *Ukrainian Food Journal,* 10(3), pp. 524–551, DOI: 10.24263/2304-974X-2021-10-3-8

Sudha M. L., Dharmesh S. M., Pynam H., Bhimangouder S. V, Eipson S. W., Somasundaram R., Nanjarajurs S. M. (2016), Antioxidant and cyto/DNA protective properties of apple pomace enriched bakery products, *Journal of Food Science and Technology*, 53(4), pp. 1909–1918, DOI: 10.1007/s13197-015-2151-2

Suman Y., Gupta R. K. (2015), Formulation of noodles using apple pomace and evaluation of its phytochemicals and antioxidant activity, *Journal of Pharmacognosy and Phytochemistry*, 4(1), pp. 99–106.

Temkov M., Velickova E., Stamatovska V., Nakov G. (2021), Consumer perception on food waste management and incorporation of grape pomace powder in cookies, *Scientific Papers. Series "Management, Economic Engineering in Agriculture and Rural Development"*, 21(1), pp. 753–762.

Theagarajan R., Malur N. L., Dutta S., Moses J. A., Chinnaswamy A. (2019), Valorisation of grape pomace (cv. Muscat) for development of functional cookies, *International Journal of Food Science & Technology*, 54(4), pp. 1299–1305, DOI: 10.1111/ijfs.14119

Tolve R., Pasini G., Vignale F., Favati F., Simonato B. (2020), Effect of grape pomace addition on the technological, sensory, and nutritional properties of durum wheat pasta, *Foods*, 9(3), 354, DOI: 10.3390/foods9030354

Tolve R., Simonato B., Rainero G., Bianchi F., Rizzi C., Cervini M., Giuberti G. (2021), Wheat bread fortification by grape pomace powder: nutritional, technological, antioxidant, and sensory properties, *Foods*, 10(1), pp. 75, DOI: 10.3390/foods10010075

Torbica A. M., Tomić J. M., Savanović D. M., Pajin B. S., Petrović J. S., Lončarević I. S., Fišteš A. Z., Blažek K. A. M. (2018), Utilization of apple pomace coextruded with corn grits in sponge cake creation, *Food and Feed Research*, 45(2), pp. 149–157, DOI: 10.5937/ffr1802149t

Tremlova B., Havlova L., Benes P., Zemancova J., Buchtova H., Tesikova K., Dordevic S., Dordevic D. (2022), Vegetarian “sausages” with the sddition of grape flour, *Applied Sciences*, 12 (4), 2189, DOI:10.3390/app12042189

Troilo M., Difonzo G., Paradiso V. M., Pasqualone A., Caponio F. (2022), Grape pomace as innovative flour for the formulation of functional muffins: how particle size affects the nutritional, textural and sensory properties, *Foods*, 11, 1799, DOI: 10.3390/foods11121799

Tseng A., Zhao Y. (2013), Wine grape pomace as antioxidant dietary fibre for enhancing nutritional value and improving storability of yogurt and salad dressing. *Food Chemistry*, 138(1), pp. 356–365, DOI: 10.1016/j.foodchem.2012.09.148

Usman M., Ahmed S., Mehmood A., Bilal M., Patil P. J., Akram K., Farooq U. (2020), Effect of apple pomace on nutrition, rheology of dough and cookies quality, *Journal of Food Science and Technology*, 57(9), pp. 3244–3251, DOI: 10.1007/s13197-020-04355-z

Valková V., Ďúranová H., Štefániková J., Miškeje M., Tokár M., Gabríny L., Kowalczewski P., Kačániová M. (2020), Wheat bread with grape seeds micropowder: impact on dough rheology and bread properties, *Applied Rheology*, 30(1), pp. 138–150, DOI: 10.1515/arh-2020-0112

Valková V., Ďúranová H., Havrlentová M., Ivanišová E., Mezey J., Tóthová Z., Gabríny L., Kačániová M. (2022), Selected physico-chemical, nutritional, antioxidant and sensory properties of wheat bread supplemented with apple pomace powder as a by-product from juice production, *Plants*, 11(9), 1256, DOI: 10.3390/plants11091256

Waldbauer K., McKinnon R., Kopp B. (2017), Apple pomace as potential source of natural active compounds, *Planta Medica*, 83(12–13), pp. 994–1010, DOI: 10.1055/s-0043-111898

Walker R., Tseng A., Cavender G., Ross A., Zhao Y. (2014), Physicochemical, nutritional, and sensory qualities of wine grape pomace fortified baked goods, *Journal of Food Science*, 79(9), pp. S1811–S1822, DOI: 10.1111/1750-3841.12554

Wang X., Kristo E., La Pointe G. (2019), The effect of apple pomace on the texture, rheology and microstructure of set type yogurt, *Food Hydrocolloids*, 91, pp. 83–91, DOI: 10.1016/j.foodhyd.2019.01.004

Wang X., Kristo E., LaPointe G. (2020), Adding apple pomace as a functional ingredient in stirred-type yogurt and yogurt drinks, *Food Hydrocolloids*, 100, pp. 105453, DOI: 10.1016/j.foodhyd.2019.105453

Xu J., Bock J.E., Stone D. (2020), Quality and textural analysis of noodles enriched with apple pomace, *Journal Food Processing and Preservation*, 44(8), pp. 1–8, DOI: 10.1111/jfpp.14579

Yadav S.K., Gupta R. (2015), Formulation of noodles using apple pomace and evaluation of its phytochemicals and antioxidant activity, *Journal of Pharmacognosy and Phytochemistry, 4(1), pp.* 99–106.

Yadav S., Malik A., Sharma D, Islam R.U., Pathera A. (2016), Development of dietary fibre enriched chicken sausages by incorporating corn bran, dried apple pomace and dried tomato pomace, *Nutrition & Food Science*, 46, pp. 16–29, DOI: 10.1108/NFS-05-2015-0049

Yalcin E., Ozdal T., Gok I. (2021), Investigation of textural, functional, and sensory properties of muffins prepared by adding grape seeds to various flours, *Journal of Food Processing and Preservation*, 46(5), 15316, DOI: 10.1111/jfpp.15316

Younas M. B., Rakha A., Sohail M., Rashid S., Ishtiaq H. (2015), Physicochemical and sensory assessment of apple pomace enriched muffins, *Pakistan Journal of Food Sciences*, 25(4), pp. 224-234.

Younis K., Ahmad S. (2015), Waste utilization of apple pomaceas a source of functional ingredient in buffalo meat sausage, *Cogent Food & Agriculture*, 1(1), 1119397, DOI: 10.1080/23311932.2015.1119397

Younis K., Ahmad S. (2018), Quality evaluation of buffalo meat patties incorporated with apple pomace powder, *Buffalo Bulletin*, 37(3), pp. 389–401.

Yu J., Ahmedna M. (2013), Functional components of grape pomace: their composition, biological properties and potential applications, *International Journal of Food Science & Technology*, 48, pp. 221–237, DOI: 10.1111/j.1365-2621.2012.03197.x

Influence of technical and technological parameters on the barley dehulling process

Yevgen Kharchenko[1], Amelia Buculei[2], Valentyn Chornyi[1], Andrii Sharan[1]

1 – National University of Food Technologies, Kyiv, Ukraine
2 – Ştefan cel Mare University of Suceava, Romania

Keywords:

Barley
Dehulling
Moisture
Grit
Husk

Article history:

Received 17.04.2022
Received in revised form 10.10.2022
Accepted 30.12.2022

Corresponding author:

Yevgen Kharchenko
E-mail: a-537@ukr.net

DOI: 10.24263/2304-974X-2022-11-4-5

Abstract

Introduction. The research aim is to determine effect of duration of dehulling, the barley size and moisture, the rotation speed of abrasive discs, the abrasive grit and the load factor of the dehuller on the dehulling index.

Materials and methods. The dehulling was carried out in laboratory dehuller (model ULZ-1) at the rotation speed of abrasive discs of 29.6±0.015 s^{-1} (1775±0.9 rpm) and 42.3±0.013 s^{-1} (2540±0.8 rpm) and removing of barley husks and meal was conducted in the laboratory aspiration duct of 60 mm width.

Results and discussion. The research has shown that the increase in the dehulling duration the weight of the barley loaded to the dehuller, the rotating rate of abrasive discs and the load coefficient of the dehuller working chamber leads to the dehulling index rise. There exists the non-linear dependence between the load coefficient of the dehuller working chamber with the minimum point of the dehulling index for the large fraction of barley 0.27–0.28 and for the small fraction of barley 0.24–0.25.

The influence of the barley weight and the load coefficient of the working chamber of the dehuller on the dehulling index occurs according to the curvilinear dependence with the minimum point of the dehulling index for the large barley fraction of 0.27–0.28 and for the small barley fraction of 0.24–0.25. The increase in the processing duration and the load coefficient of the working chamber of the dehuller leads to the increase of the dehulling index, but at the same time the minimum point of the dehulling index decreases from 0.29 to 0.25.

As the size of the barley grows, the dehulling index decreases. The gain in moisture of the barley leads to the decrease of the dehulling index according to the linear dependence for both large and small barley fractions. Moreover, the small fraction has the bigger values of the dehulling index than the large one.

The moisture influence on the dehulling index has linear dependence for both large and small barley fractions. As moisture increases the dehulling index decreases linearly, but at the same time the large barley fraction had lower values of the dehulling index than the small one.

The increase in abrasive discs grit leads to the dehulling index decrease according to the curvilinear dependence. At the grit of 80 the dehulling index gets the constant value and its change depends on the duration of processing.

Conclusion. The influence of technological parameters of barley grain on the dehulling index has linear dependence, and machine parameters affect the dehulling index according to curvilinear dependency. These results must be considered when evaluating the effectiveness of dehulling and the development of the process model.

Introduction

The barley grain is the basis for various food products, such as groats and flour. During the barley processing it is treated to separate the hull. The process of dehulling has not been studied enough so as to predict its effectiveness during the use of various hullers.

The process of barley dehulling is influenced by the load on the machine, the distance between abrasive discs and the sieve plate, the abrasive discs grit, and the treatment duration in the dehulling machine (Izydorczyk et al., 2016). This process is also influenced by the moisture and the size of barley (Bhatty, 1997; Sharma et al., 2010). Different barley varieties have different capacities for the dehulling (Edney et al., 2002; Felizardo et al., 2018).

Abrasive surfaces with the lower grit lead to quicker removing barley hull, whereas abrasive surfaces with greater grit result in a thinner product (Flores et al., 2007; McCluskey, 2016). The dependence between abrasive discs grit and dehulling index is not stated, therefore further investigation is required.

The increase of the grain weight in the dehulling machine leads to the increase of the dehulling index according to the nonlinear dependence (Kharchenko et al., 2017; Vereshchinskii, 2011); the dependences of the dehulling index during the moisture change, the size and the weight of the loaded grain in the machine have not been studied yet.

The increase in the barley treatment duration leads to the linear increase of the dehulling index (Kharchenko et al., 2017; Sharma et al., 2010), but there is no explanation of the dehulling index linear dependence from the treatment duration.

Baltabaev et al. (2011) studied the effectiveness of barley dehulling in the horizontal dehulling machine of continuous operation. This analysis shows that at the rotation speed of the rotor of 1800 rpm the dehulling coefficient is higher than at the rotation speed of 1500 rpm, but at the rotation speed of the rotor of 1650 rpm the coefficient is much less than at the speed of 1500 rpm. This data requires verification and justification. Baltabaev et al., (2011) showed the linear dependence of the dehulling index from the dehulling duration in the machine at varying rotation speeds of the rotor of the machine.

Olkku et al. (2005) illustrated the linear dependence of the husk weight change from the barley moisture; however, there are no similar dependences between the barley moisture and the dehulling index. The increase of the barley moisture to 14% decreases the dehulling duration (Sharma et al., 2010). The impact of the barley moisture and the size on its dehulling effectiveness requires further investigations (Edney et al., 2002).

The similarity of the barley size also influences the dehulling index (Izydorczyk et al., 2016). Sharma et al. (2010) showed that there exists negative correlation between the dehulling coefficient and the bulk density. The barley with the bigger kernel weight requires more time for processing to achieve necessary values of the dehulling index (Edney et al., 2002). This proves the influence of the barley size on the dehulling index and requires further investigations of the influence of the barley size and moisture on the dehulling index under the conditions of varying treatment duration, weight of the loaded grain into the dehuller, different load coefficient of the machines' working chamber.

The research aim is to determine effect of duration of dehulling, the barley size and moisture, the rotation speed of abrasive discs, the abrasive grit and the load factor of the dehuller on the dehulling index.

Materials and methods

Preparation of the barley samples

The barley grain was cleaned in the laboratory aspiration channel before carrying out research to separate light impurity. The removing of impurity and separation into the large and small fraction was conducted in the Carter-Day dockage tester (Carter-Day Co., Minneapolis, MN) (Arya et al., 2011; Fan et al., 2000; McCluskey, 2016; Sissons et al., 2000). The riddling of the grain sieve of 3.0×20 mm allowed to get a large fraction and the scalp of the grain sieve of 3.0×20 mm and the riddling of the grain sieve of 1.8×20 mm allowed to get a small fraction of the barley grain. The scalp of the grain sieve of 1.8×20 mm removed small impurity and directed it to wastes.

After their cleaning and fractions' separation there was defined the grain moisture (ISO 712:2009(E). Cereals and cereal products. Determination of moisture content), the weight of 1000 grains on a dry basis (ISO 520:2010. Cereals and pulses – Determination of the mass of 1000 grains) and the bulk density (ISO 7971-3:2009(E). Cereals – Determination of bulk density, called mass per hektolitre) in each barley grain fraction.

The barley with the weight of 1000 grains on a dry basis A=56 g and the bulk density – γ=711±8 kg/m³ was attributed to the large fraction, and the barley with the weight of 1000 grains on a dry basis A=43 g and the bulk density – γ=686±3 kg/m³ was attributed to the small fraction. The initial moisture of both fractions was 12.6±0.2%.

Studying the impact of the duration of treatment on the barley dehulling

The barley dehulling was carried out in the dehuller ULZ-1 (Olis, Odesa, Ukraine), with the abrasive discs 14AF46K7V and the grit 40. The size of the openings of the grain sieve in the dehulling machine was Ø 2.3 mm.

The studying of the impact of the duration of treatment on the barley dehulling index was carried out according to the following methods. The sample weight of 100±0ю1 g was loaded into the dehuller and hulled during 20, 40, 60, 80, 100 s. The change of the dehulling duration was provided with the timer of the dehulling machine. The large and the small barley fractions were hulled separately under similar conditions.

The studying of the dehulling kinetics of the large and small barley fractions was conducted at the rotation speeds of the dehuller's abrasive discs ω=29.6±0.015 s^{-1} (1775±0.9 rpm) and ω=42.3±0.013 s^{-1} (2540±0.8 rpm). The rotation speed was changed by means of throwing over the belt on the engine pulley and abrasive discs.

The rotation speed of abrasive discs was measured by means of the optical tachometer Testo 460. The reflecting tape was attached to the dehuller's pulley, then the dehuller was turned on in the idle position without grain, the tachometer beam was pointed at the pulley and the readings of the tachometer were taken.

Dehuller works as follows (Figure 1). The grain is loaded into the hopper (11). At a certain time, the latch (10) opens and the grain is poured into the working chamber between the abrasive discs (8), the screen (9) and the housing (1). The distance between the abrasive discs (8) and the screen (9) is 0.015±0.001 m. Grain moves in a circle admiring abrasive discs (8). During the movement, the grain interacts with the screen and the friction between grains. After stopping the dehuller, the latch (12) opens and the dehulling products are poured into the middle hopper. Products that have passed through the screen are collected in two side bins. Abrasive discs (8) with a diameter of 0.150±0.0001 m are firmly pressed together and do not have gap between them.

After the dehulling the mixture of the derived products was passed through the laboratory aspiration channel with 60 mm width, where the separation of the husk and the meal from the kernel occurred. To avoid getting of separate grains into the husk tank, the air flow rate in the channel was decreased by means of speed reduction of the fan impeller by using variable speed drive. After each replicate the kernel was visually examined for the presence of the husk and the meal. Whenever necessary, the cleaned kernel was passed through the aspiration channel repeatedly. The mixture of the husk and the meal was also examined for the presence of the kernel. The Figure 1 shows the scheme of the barley dehulling (Kharchenko et al., 2018).

The cleaned barley kernel was weighted and the dehulling index was calculated according to the formula (Donkelar et al., 2015; Felizardo and Freire, 2018; Lawton et al., 1989):

$$I = \frac{m_1 - m_2}{m_1} \cdot 100 \qquad (1)$$

where I is the barley dehulling index, %; m_1, m_2 are the weight of the grain before the dehulling and the weight of the barley kernel after the dehulling correspondingly, g.

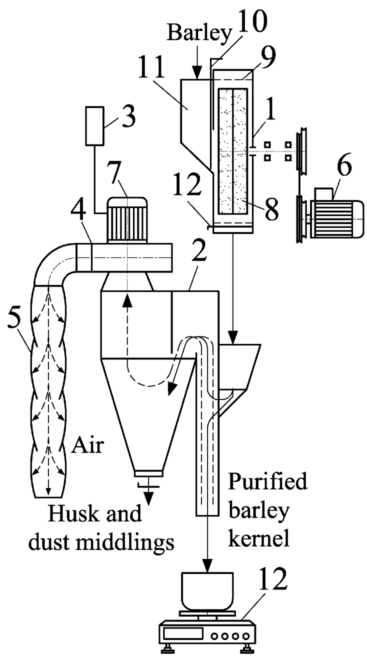


Figure 1. Barley dehulling scheme:
1 – dehuller; 2 – laboratory aspiration channel; 3 – variable speed drive; 4 – fan;
5 – filter; 6,7 – engine; 8 – abrasive discs; 9 – the size of the openings Ø 2.3 mm;
10 – choke; 11 – bin; 12 – scale.

The studying of the dehulling kinetics was carried out for both dry and moist, large and small barley fractions. The estimated amount of water was added in large and small barley fractions, each of 2±0.1 kg, assuming that the final water content of each fraction was 16.0%. The water amount was calculated according to the formula (Barnwal et al., 2010):

$$G_w = G_g\left(\frac{W_1 - W_0}{100 - W_1}\right), \quad (2)$$

where G_w, G_g are the weight of water and the weight of grain, correspondingly, g; W_0, W_1 are the initial and specified grain moisture, correspondingly, %.

After adding water there was a three days' grain maturing process. During the studying process the actual moisture of the barley of each fracture was defined.

Impact of barley weight and the load coefficient on the barley dehulling index

The impact of barley weight on the dehulling index was found out by increasing the weight of the grain loaded into the dehuller in the amount of 40, 80, 120, 160 and 200 g. Notice that in doing this the rotation speed of abrasive discs of the dehuller was constant and equal to 29.6±0.015 s^{-1}, the dehulling duration was constant and equal to 25 s. Abrasive discs were not changed and were the same as during research, as illustrated in the clause 2.2. The dehulling index was calculated according to the formula 1.

The load coefficient of the working chamber was calculated in accordance with the formula (Kharchenko et al., 2017):

$$K = \frac{V_g}{V_m} \quad (3)$$

where K is load coefficient of the dehuller's working chamber; V_s is grain volume, loaded into the dehuller, m^3; V_m is volume of the dehuller's working chamber, m^3.

The grain volume was calculated using the formula:

$$V_g = \frac{m}{\gamma} \quad (4)$$

where m is weight of the barley grain, loaded into the dehuller, kg; γ is barley bulk density, kg/m^3.

The volume of the dehuller's working chamber was calculated using the formula:

$$V_m = \frac{\pi D^2}{4}\cdot H - \frac{\pi d^2}{4}\cdot h \quad (5)$$

where D, d is the diameter of the grain sieve of the dehuller and the abrasive disc correspondingly, m; H, h is the height of the grain sieve of the dehuller and abrasive discs correspondingly, m.

The diameter of the grain sieve was D=0.165±0.0001 m, the diameter of discs was d=0.15±0.0001 m. The height of the grain sieve was H=0.058±0.001 m, the width of abrasive discs was h=0.04±0.0001 m.

The analysis was conducted separately for the large and small fractions of both dry and moistened grain.

After each replication the dehulling products were passed through laboratory aspiration channel to separate the husk from the dust middling. The dehulling index was calculated using the methods described in the clause 2.2.

Impact of loading and duration of treatment on the barley dehulling index

The large barley fraction was hulled in the amount of 40±0.1 g to 200±0.1 g at intervals of 40 g. The rotation speed of abrasive discs was constant and equal to 29.6±0.015 s^{-1}. The dehulling duration varied from 40 to 100 s at intervals of 20 s. The research was conducted only with the large fraction with the level of moisture 12.6±0.2%. The product purification as well as the dehulling index determination was carried out similarly to the description in the clause 2.2 (Kharchenko et al., 2018).

Impact of moisture on the barley dehulling index

To define the impact of the barley moisture on the dehulling process effectiveness, the large and small fractions of the barley were moistened to 16.0%.

Moisturizing and maturation of the barley was carried out according to the following techniques. Six containers with compact lids were filled with 200±0.1 g of barley. The amount of water calculated using formula 2 was added in each container. It was thoroughly mixed for 10 minutes and left in closed containers for three days for maturation and homogenous distribution of moisture over the barley grain (Kharchenko et al., 2018).

After moisturizing the dehuller was loaded with 160±0.1 g of barley, the dehulling occurred with further separation of hull in the aspiration channel. The dehulling index was calculated using techniques showed in clause 2.2. The dehulling duration for all the sample weights was 25 s, at the rotational speed of abrasive discs 29.6±0.015 s^{-1}. The residue of the moistened grain was used to define the actual moisture (Kharchenko et al., 2018).

Abrasive discs' grit impact on the barley dehulling index

To find out the impact of abrasive discs' grit on the dehulling index three abrasive discs were used: 14AF46K7V, 14AF60K7V, 14AF80K7V with the grit 40, 60, and 80 correspondingly. The large fractions of barley were hulled with the alternate change of abrasive discs in the dehuller. The rotation speed of abrasive discs was 29.6±0.015 s^{-1}. The sample weights of 100±0.1 g were put into the dehuller and hulled for 20, 40, 60, 80, 100 s. Purification of dehulling products was carried out in accordance with techniques shown in clause 2.2.

Results and discussion

Impact of the barley size and moisture on the dehulling index at varying speeds of abrasive discs rotation

The Figure 2 shows the results of dehulling kinetics research of large and small barley fractions with the moisture of 12.6±0.2%, various speeds of abrasive discs' rotation of the dehuller 29.6±0.015 s^{-1} and 42.3±0.013 s^{-1}.

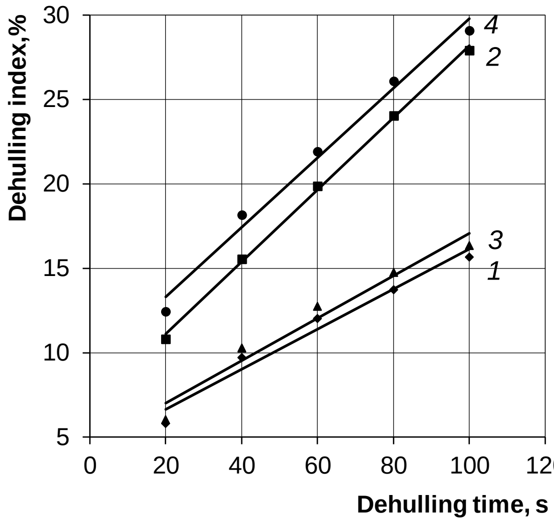


Figure 2. Effect of dehulling duration of barley on dehulling index:
Moisture of barley – 12.6±0.2%;
1 – A=56 g, ω=29.6±0.015 s^{-1};
2 – A=56 g, ω=42.3±0.013 s^{-1};
3 – A=43 g, ω=29.6±0.015 s^{-1};
4 – A=43 g, ω=42.3±0.013 s^{-1}
(A is the weight of 1000 grains on a dry basis, g; kg/m³; ω is rotational speed of abrasive discs, s^{-1})

The Figure 2 shows that the increase of the rotation speed of abrasive discs leads to the increase of the dehulling index ($P<0.05$) of both large and small barley fractions. The inclination of the lines increased for both barley fractions ($P<0.05$), that testifies to the higher intensity of abrasive discs' impact on the barley grain as the rotation speed of abrasive discs rises.

All things being equal, the dehulling index of the small fraction was higher than the dehulling index of the large barley fraction ($P<0.05$). It gives the evidence that the dehulling resistance of the small barley fraction at the moisture of 12.6±0.2% is less than the dehulling resistance of the large fraction at the same grain moisture. At the barley moisture of 12.6±0.2% the impact of the barley size on the dehulling index was significant only at the rotation speed of abrasive discs of 42.3±0.013 s^{-1} ($P<0.05$). The impact of the barley size on the dehulling index at the rotation speed of abrasive discs of 29.6±0.015 s^{-1} was not significant and ranged up to 1.0% ($P>0.05$). The experiment has let as to conclude that the slower is the rotation speed of the dehuller's abrasive discs, the less the size of the grain influences the dehulling index.

The Figure 3 shows the results of dehulling index research of the large and small barley fractions at the moisture of 16.0±0.2% and the rotation speed of abrasive discs of 29.6±0.015 s^{-1} and 42.3±0.013 s^{-1}.

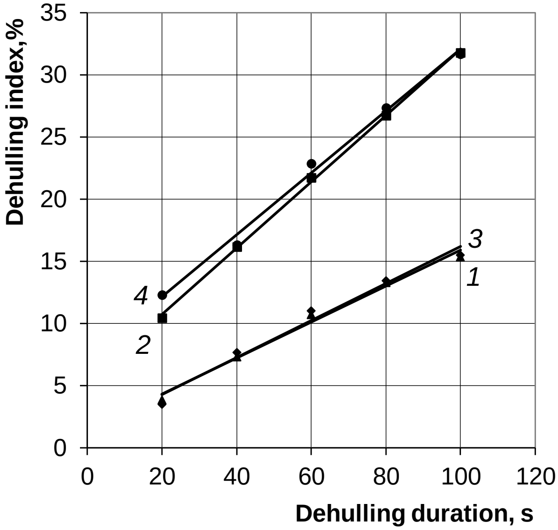


Figure 3. Effect of dehulling duration of barley on dehulling index:
Moisture of barley – 16.0±0.2%;
1 – A=56 g, ω=29.6±0.015 s^{-1};
2 – A=56 g, ω=42.3±0.013 s^{-1};
3 – A=43 g, ω=29.6±0.015 s^{-1};
4 – A=43 g, ω=42.3±0.013 s^{-1}
(A is the weight of 1000 grains on a dry basis, g; kg/m³; ω is rotational speed of abrasive discs, s^{-1})

Analysis of data presented in Figure 3 show that the size of barley with the moisture content of 16.0±0.2% does not influence significantly the dehulling of the large and small grain (P>0,05). The most substantial factors that changed the dehulling index were the rotation speed of abrasive discs and the processing duration. Comparing the results shown in Figure 2 and 3 one can see that the size has an impact only during dry barley hulling (P<0.05), whereas the increase of the barley moisture reduces the influence of the barley size substantially. The results shown in Figure 2 and 3 also testify the fact that the rotation speed of abrasive discs is the factor that increases the dehulling index regardless of the barley moisture and size.

The dependence of the dehulling index from the duration of treatment is described with linear dependences (Sharma et al., 2010). This is due to the fact that the grain is an anisotropic body, hence its properties in various areas are different and the strength of the kernel and hull does not influence the kinetics of the process. The hull strength is much higher than the endosperm strength. The strength of fruit membranes, seed coats and the aleurone layer that makes 33 MPa at the grain moisture 10–12%; under the same conditions the endosperm strength is not more than 3 MPa that is 11 times less than the hull strength. Given this, one can suggest that during the cutting of hulls and proceeding to the endosperm there has to occur a shift from linear to curvilinear dependence because the endosperm has lower strength and being equally loaded from the side of abrasive discs it has to separate in higher quantities from the kernel than from the hull. However, the experimental data gives the evidence about the linear dependence of the dehulling index and the grain duration of treatment; besides, the linear dependence testifies to the constant dehulling speed (Lawton et al., 1996). All of this implies that the kernel and hull strengths do not influence the linear dependences of the dehulling process all other things being equal.

The linear dependence of the barley kernel strength from the dehulling duration (Bhatty, 1997; Kharchenko et al., 2018) can be explained by the influence of the scale factor of the particles that are dehulled. As the size of the particles reduces the number of structural defects decreases that leads to the strengthening of these particles. The grain strength influences the dehulling index if different varieties of the barley are hulled because they have different strength all other things being equal (Bhatty et al., 1998; Brennan et al., 2017).

Impact of the barley size and moisture on the dehulling index at varying grain weight and load coefficient of the dehuller

The Figure 4 shows the impact of the grain weight loaded into the dehuller, the barley size, and the moisture on the dehulling index. As the moisture of large and small barley fractions increased, the dehulling index decreased in comparison with similar conditions of dry grain fractions' dehulling ($P<0.05$). Dehulling indices of small moistened barley fractions were higher than the indices of dehulling of large moistened fractions ($P<0.05$). It is proved by the fact that the small fraction had the lower dehulling resistance than the large barley fraction (Edney et al., 2002).

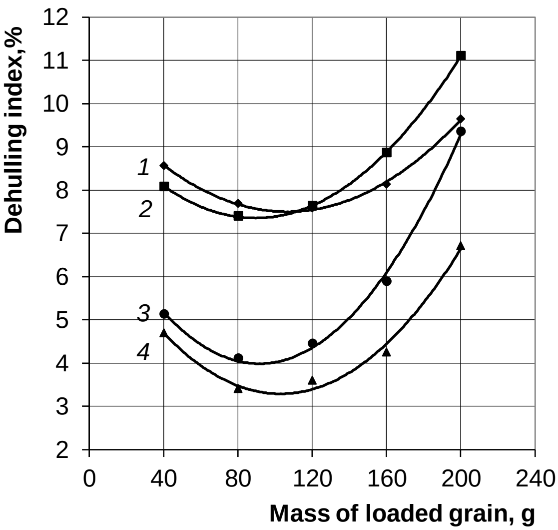


Figure 4. Effect of loaded grain weight on dehulling index:
1 – A=56 g; W=12.6%;
2 – A=43 g; W=12.6%;
3 – A=43 g; W=15.0%;
4 – A=56 g; W=15.0%
(A is the weight of 1000 grains on a dry basis, g; kg/m^3; W is moisture of grain,%)

The data in Figure 4 indicate that the barley moisture influences the dehulling index the most with the increase of the barley weight loaded into the dehuller ($P<0.05$). The reduction of the dehulling index of large and small barley fractions with the moisture increase can be explained by the fact that the moistened barley changed its structural-mechanical characteristics and moved from brittle to elastic-plastic state that resulted in the increase of the hull viscosity (Bargale et al., 1995) and led to the increase of dehulling resistance.

The calculation of the grain weight loaded into the dehuller as well as the barley-unit enables us to express these values in terms of the coefficient of working chamber load of the dehuller, which is a nondimensional quantity. This gives us un opportunity to compare the effectiveness of dehulling process in various dehullers similar in design. The Figure 5 shows us the dependencies of the dehulling index from the load coefficient of working chamber of the dehuller at various barley moisture and size. The general view of the curves is similar to those provided in Figure 4, but there are some differences that are connected with different bulk density of the large and small barley.

The data in Figure 5 show that curvilinear dependences have minimum points of the dehulling index: for the large barley fraction at load coefficients of working chamber 0.27–0.28, and for the small barley fractions at load coefficients of working chamber 0.24–0.25. The increase of the load coefficient of the device from 0.24–0.28 to 0.53–0.55 leads to the increase in the dehulling index regardless of the barley moisture and size ($P<0.05$). The increase of the load coefficient of the device from 0.11 to 0.24–0.28 on the contrary, decreases the dehulling index ($P<0.05$).

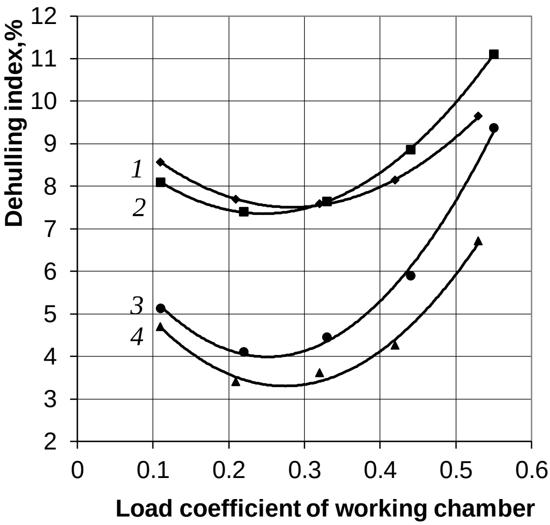


Figure 5. Effect of load coefficient of working chamber and the barley moisture on dehulling index:
1 – A=56 g; W=12.6%;
2 – A=43 g; W=12.6%;
3 – A=43 g; W=15.0%;
4 – A=56 g; W=15.0%
(A is the weight of 1000 grains on a dry basis, g; kg/m³; W is moisture of grain,%)

The curvilinear dependence of the dehulling index and the load coefficient is explained by the interaction peculiarities of abrasive discs and the barley. At load coefficient values of the working chamber of the dehuller from 0.11 to 0.28 the area of pseudo rare grain mass appears with the random motion of separate barley grains as affected by the rotor rotation. The contact of the grains with the abrasive discs' surface is of short time. And herewith radially extending constituents of the interaction forces dominate those ones tangent to the working surface of the rotor. These conditions do not contribute to the effective barley dehulling (Vereshchinskii, 2011).

The increase of the load coefficient of the dehuller's working chamber from 0.28 до 0.53–0.55 leads to the qualitative change of interaction character of the abrasive discs' working surface with barley grain. The flow of pseudo rare grain mass becomes thicker, the tangent interaction forces increase, the working surface of abrasive discs "grips" the barley grain, that results in more durable phase contact. Under these conditions, the dehulling intensity as well as the processing intensity of the barley surface increases (Vereshchinskii, 2011).

The load coefficient of the working chamber of the dehuller can be considered as a factor that increases the dehulling index provided that the value of the load coefficient of the dehuller's working chamber exceeds the minimum point of the dehulling index, which is in the range of 0.24–0.28.

The differences in the load coefficients for large and small barley fractions can be explained by the fact that the bulk density influences the load coefficient of the working chamber of the dehuller ($P<0.05$) and this value is a part of the calculation formula 4. The table 01 shows the differences in the load coefficients of the working chamber of the dehuller given that the weight of the loaded barley is equal but the bulk density is different.

Table 1

Load coefficients of the working chamber of the dehuller depending from the barley bulk density

Weight of the grain loaded into the dehuller, g	Load coefficient of large fraction at bulk density 711±8 kg/m³	Load coefficient of small fraction at bulk density 686±3 kg/m³
40±0.1	0.11	0.11
80±0.1	0.21	0.22
120±0.1	0.32	0.33
160±0.1	0.42	0.44
200±0.1	0.53	0.55

Influence of the dehulling duration and the load coefficient of the working chamber of the dehuller on the dehulling index of large barley fraction

The Figure 6 gives the results of research of the impact of the load coefficient of the working chamber of the dehuller and the barley duration of treatment on the dehulling index. As the duration of treatment and the load coefficient of the working chamber increase curvilinear dependences change their curvature so as the dehulling index rises ($P<0.05$). All these testifies to the mutual influence of the load coefficient and the duration of treatment on the dehulling index. This kind of dependencies can be explained by the fact that the increase in the dehulling duration causes more separations of hulls and peripheral particles from the kernel, and the rise in the load coefficient of the working chamber of the dehuller increases additionally the kernel interaction with abrasive discs.

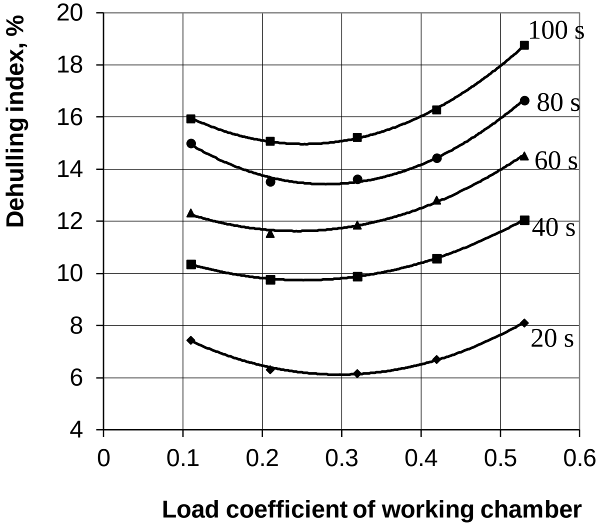


Figure 6. Effect of load coefficient of working chamber on dehulling index at different treatment duration

It should be noted that as the duration of treatment increases, the minimum point of the dehulling index decreases from 0.29 to 0.25 (P<0.05).

Impact of the barley moisture on the barley dehulling index

The Figure 7 gives the results of research of the barley moisture influence on the dehulling index.

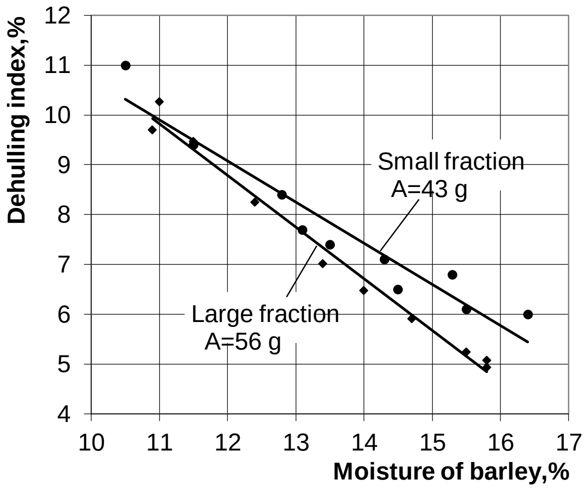


Figure 7. Effect of moisture of barley on dehulling index
(Rotation speed of abrasive discs 29.6±0.015 s^{-1})

As moisture increased the dehulling index decreased linearly for both large and small barley fractions ($P<0.05$). The small fraction's dehulling index was higher than the large fraction's dehulling index ($P<0.05$), and that proves the fact that the large barley creates stronger resistance to the dehulling than the small one (Edney et al., 2002).

The decrease in the dehulling index with the increase in barley moisture can be explained by the fact that the increase of the grain moisture leads to the increase of plastic properties of hulls that during the dehulling process create stronger resistance to dehulling (Bargale et al., 1995; Bhatty, 1997).

Impact of the abrasive discs grit on the dehulling index of the large barley fraction

The Figure 8 gives the results of research of the dehulling index of the large barley fraction with moisture of 10.9±0.05% in the dehuller with abrasive discs of varying grit all other things being equal. The analysis of data, shown in Figure 8 indicates that as the abrasive discs' grit increases, the dehulling index decreases ($P<0.05$). This is explained by the decreasing of discs' abrasive grain sizes (Flores et al., 2007).

Direct dependences, given in Figure 8 give the indirect understanding about the impact of the abrasive discs' grit on the dehulling index. Having transformed Figure 8 in a way that X-axis stands for abrasive discs' grit and the Y-axis stands for the dehulling index, we will get the dependences of the influence of abrasive discs' grit on the dehulling index at varying values of duration of treatment. The results of research are given in Figure 9.

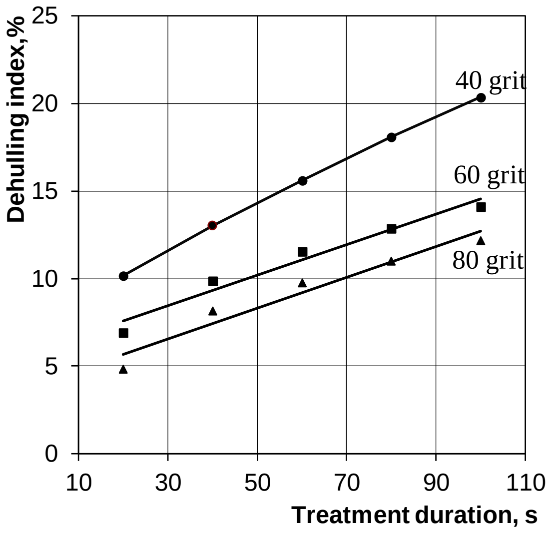


Figure 8. Effect of treatment duration on dehulling index at different grit of abrasive discs

The data, shown in Figure 9, indicate that there exists a nonlinear dependence between the dehulling index and the abrasive discs' grit, which is steadily growing with the increase in the barley duration of treatment. The Figure 9 also shows that the increase in the abrasive discs' grit of 80 leads to the constant value of the dehulling index.

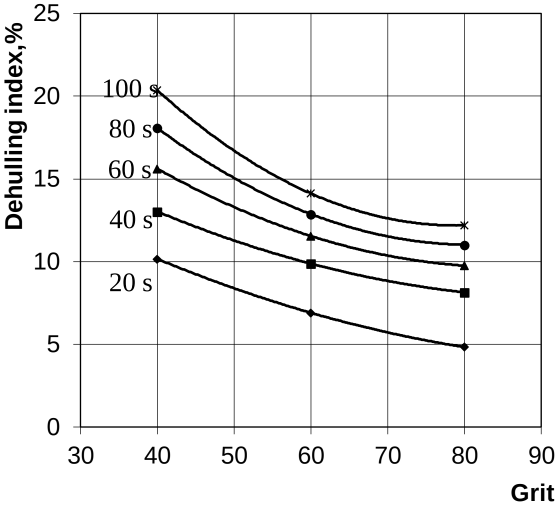


Figure 9. Effect of abrasive discs grit on dehulling index at different treatment duration

This development of the dehulling process results from the decrease of the abrasive grain size that plays a dominant role during the barley hulls' destruction. The increase in the abrasive discs' grit causes the decrease of the overall abrasive grain sizes that leads to the decrease in the number of hulls removed from the surface of the barley kernel by abrasive grains (Flores et al., 2007). Removing of hulls occurs not only by means of friction (Lawton et al., 1989), but also by means of sliding cutting, where the breakdown voltages concentrate on the microcutting abrasive grains and the bulk weight of the material is practically not changed (Agarwal, 2019).

Conclusions

Dehulling index increases at the increase of the barley dehulling duration, abrasive discs' rotation speed and the load coefficient of the working chamber more than 0.24–0.28. The increase in the barley size, its moisture content and the abrasive discs' grit leads to the dehulling index decrease.

The increase of the rotation speed of abrasive discs leads to the increase of the barley dehulling index.

All other things being equal, the large barley fraction's dehulling index is less than the small fraction's dehulling index. The size of the barley grains has a greater impact on dehulling index at low barley moisture content (12.6±0.2%) and the abrasive discs' rotation speed of 42.3±0.013 s^{-1}. The decrease in the abrasive discs' rotation speed from 42.3±0.013 s^{-1} to 29.6±0.015 s^{-1} results in an inessential influence of the barley size on the dehulling index.

The influence of the barley weight and the load coefficient of the working chamber of the dehuller on the dehulling index occurs according to the curvilinear dependence with the minimum point of the dehulling index for the large barley fraction of 0.27–0.28, and for the small barley fraction of 0.24–0.25. The increase in the duration of treatment and the load coefficient of the working chamber of the dehuller leads to the increase of the dehulling index, but at the same time the minimum point of the dehulling index decreases from 0.29 to 0.25.

The moisture influence on the dehulling index has linear dependence for both large and small barley fractions. As moisture increases the dehulling index decreases linearly, but at the same time the large barley fraction had lower values of the dehulling index than the small one.

The increase of the abrasive discs' grit from 40 to 80 decreases the dehulling index in accordance with the curvilinear dependence. All other things being equal as the abrasive discs' grit reaches 80 or more, the dehulling index stops changing, becoming a constant value.

References

Agarwal S. (2019), On the mechanism and mechanics of wheel loading in grinding, *Journal of Manufacturing Processes*, 41, pp. 36–47, DOI: 10.1016/j.jmapro.2019.03.009.

Arya S., McKinnon J. J. (2011), The effects of a low lignin hull, high oil groat oat on the performance and carcass characteristics of feedlot cattle, *Canadian Journal of Animal Science*, 91, pp. 685–693, DOI: 10.4141/CJAS2011-052.

Baltabaev U. N., Tursunkhodzhaev P. M. (2011), The research of the effects of design factors and technological processes of the dehuller on the effectiveness of the barley dehulling, *Grain Storage and Processing*, 11, pp. 65–67.

Bargale P.C., Irudayaraj J. (1995), Mechanical strength and rheological behaviour of barley kernels, *International Journal of Food Science and Technology*, 30, pp. 609–623, DOI: 10.1111/j.1365-2621.1995.tb01409.x.

Barnwal P., Singh, K. K., Mridula D., Kumar R., Rehal J. (2010), Effect of moisture content and residence time on dehulling of flaxseed, *Journal of Food Science and Technology*, 47(6), pp. 662–667, DOI: 10.1007/s13197-010-0113-2.

Bhatty R. S. (1997), Milling of regular and waxy starch hull-less barleys for the production of brain and flour, *Cereal Chemistry*, 74(6), pp. 693–699, DOI: 10.1094/CCHEM.1997.74.6.693.

Bhatty R. S., Rossnagel B. G. (1998), Comparison of pearled and unpearled Canadian and Japanese barleys, *Cereal Chemistry*, 75(1), pp. 15–21, DOI: 10.1094/CCHEM.1998.75.1.15.

Brennan M., Shepherd T., Mitchell S., Topp C. F. E., Hoad S. P. (2017), Husk to caryopsis adhesion in barley is influenced by pre- and post-anthesis temperatures through changes in a cuticular cementing layer on the caryopsis, *BMC Plant Biology*, 17(1), pp. 1–19, DOI: 10.1186/s12870-017-1113-4.

Donkelar L. H. G., Noordman T. R., Boom R. M., Goot A. J. (2015), Pearling barley to alter the composition of the raw material before brewing, *Journal of Food Engineering*, 150, pp. 44–49, DOI: 10.1016/j.jfoodeng.2014.10.024.

Edney M. J., Rossnagel B. G., Endo Y., Ozawa S., Brophy M. (2002), Pearling quality of Canadian barley varieties and their potential use as rice extenders, *Journal of Cereal Science*, 36(3), pp. 295–305, DOI: 10.1006/jcrs.2001.0466.

Fan J., Siebenmorgen T. J., Yang W. (2000), A study of head rice yield reduction of long- and medium-grain rice varieties in relation to various harvest and drying conditions, *American Society of Agricultural Engineers*, 43(6), pp. 1709–1714, DOI: 10.1303/2013.3072.

Felizardo M. P., Freire J. T. (2018), Characterization of barley grains in different levels of pearling process, *Journal of Food Engineering*, 232, pp. 29–35, DOI: 10.1016/j.jfoodeng.2018.03.017.

Flores R. A., Hicks K. B., Wilson J. (2007), Surface abrasion of hulled and hulles barley: physical characterization of the milled fractions, *Cereal Chemistry*, 84(5), pp. 485–491, DOI: 10.1094 /CCHEM-84-5-0485.

Izydorczyk M.S., Dexter J.E. (2016), Barley: Milling and Processing, In: Wrigley C., Corke C., Seetharaman C., Faubion C. (2th ed.), *Encyclopedia of Food Grains*, Academic Press, DOI: 10.1016/B978-0-12-394437-5.00154-6.

Kharchenko Y. I., Sharan A. V. (2017), Pearling of barley grain, *Grain Storage and Processing*, 9, pp. 28–31.

Kharchenko Y. I., Sharan A. V., Chornyi V. M., Yeremeeva O. A. (2018), Effect of technological properties of pea seeds and processing modes on efficiency of its dehulling, *Ukrainian Food Journal*, 7(4), pp. 589–604. https://doi.org/10.24263/2304-974X-2018-7-4-5.

Lawton J. W., Faubion J.M. (1989), Measuring kernel hardness using the tangential abrasive dehulling device, *Cereal Chemistry*, 66(6), pp. 519–524.

McCluskey P. (2016), Dockage Testers, In: McCluskey P. (ed.), *Equipment Handbook*, Washington, pp. 37–53.

Olkku J., Kotaviita E., Salmenkallio-Marttila M., Sweins H., Home S. (2005), Connection between structure and quality of barley husk, *Journal of the American Society of Brewing Chemists*, 63(1), pp. 17–22, DOI: 10.1094/ASBCJ-63-0017.

Oomah B. D., Mazza G., Kenaschuk E. O. (1996), Dehulling characteristics of flaxseed, *LWT – Food Science and Technology*, 29(3), pp. 245–250, DOI: 10.1006/fstl.1996.0036.

Sharma P., Gujral H. S. (2010), Milling behavior of hulled barley and its thermal and pasting properties, *Journal of Food Engineering*, 97, pp. 329–334, DOI: 10.1016/j.jfoodeng.2009.10.025.

Sissons M.J., Osborne B.G., Hare R.A., Sissons S.A., Jackson R. (2000), Application of the single-kernel characterization system to durum wheat testing and quality prediction, *Cereal Chemistry*, 77(1), pp. 4–10, DOI: 10.1094/CCHEM.2000.77.1.4.

Vereshchinskii A. P. (2011), The properties and peculiarities of interaction of grinding-wheels with grain during the dehulling process, *Grain Storage and Processing*, 11(149), pp. 62–65.

Effect of rosehip flour on the properties of wheat dough and bread

Rosen Chochkov[1], Denka Zlateva[2], Petya Ivanova[1], Dana Stefanova[2]

1 – University of Food Technologies, Plovdiv, Bulgaria
2 – University of Economics, Varna, Bulgaria

Keywords:

Wheat bread
Rosehip
Flour
Rheology

Article history:

Received 10.09.2022
Received in revised form 17.12.2022
Accepted 30.12.2022

Corresponding author:

Rosen Chochkov
E-mail:
rosen4o4kov@abv.bg

DOI:
10.24263/2304-974X-2022-11-4-6

Abstract

Introduction. The aim of the present study was to investigate the effect of rosehip flour on some properties of wheat dough and bread.

Materials and methods. Bread was prepared from wheat flour with the addition of rosehip flour in the amount of 5, 10 and 15% to replace the equal amount of the wheat flour. The used methods are standardized and generally accepted for evaluation of bread.

Results and discussion. It was found that the addition of different amounts of rosehip flour to wheat flour affected the intensity of gas formation, as the percentage of rosehip flour added had increased, the intensity of gas formation decreased. When adding 5% rosehip flour, there was no significant deterioration of gas formation. Incorporation of rosehip flour into wheat dough resulted in a decrease in water absorption and degree of softening and the lowest results were found in the sample with 15% rosehip flour added. In terms of dough development time and consistency, there were no significant differences between the samples. Dough stability was found to be higher in the samples containing rosehip flour, with the highest value reported for the sample with 5% rosehip flour. Dough and bread color characteristics decreased with increasing the rosehip flour quantity. Darker colour of rosehip flour enriched samples could be due to the original colour of rosehip fibre, which is rather brown and slightly reddish. The substitution of wheat flour with rosehip flour resulted in a decrease in volume, specific volume, height/diameter ratio and baking loss of the wheat bread. Some of the sensory parameters of bread (crust color, aroma and taste) in the rosehip flour supplemented samples were rated higher by the panelists compared to the control sample, regardless of the amount of rosehip flour added.

Conclusions. The rosehip flour could be successfully used as an additive in wheat bread formulation. In the sensory assessment bread samples with rosehip flour in terms of some properties such as crust color, aroma and taste had higher scores than the control sample.

Introduction

Application of novel natural additives to improve the health value of different traditional food products is a new trend in the food preparation (Stabnikova et al., 2021), and among them berries being rich sources of bioactive constituents became very popular (Paredes-López et al., 2010). Rosehip berries have been used, as a powder or an extract, in various formulations in baking to enhance the bread's nutritional value (Kaiyun, 2016). Rosehips (*Rosa spp*.) are members of the genus *Rosa*. Approximately up to 200 species are grown in the world, 25% of them were found in Turkey (Murathan et al., 2016). Members of the *Rosaceae* family have long been used for food purposes. Rosa species have attracted the attention due to their antioxidant, antimicrobial and other properties (Bhave et al., 2017).

Rosehip fruits from the family of *Rosaceae* are an important source of proteins, carbohydrates, energy, sugars, particularly the reducing sugars, ascorbic acid, antioxidants, carotenoid pigments, minerals, organic and fatty acids (Böhm et al., 2003; Demir et al., 2001; Ercisli, 2007; Murathan et al., 2016). Rosehip fruits are used for avitaminosis and in other cases, related to the decrease of immunological defence and vital tonicity of the organism. They contain vitamin C, which accumulates in large quantities at the beginning of fruit ripening. It is well known that vitamin C is used in baking as an oxidant improver to strengthen gluten and improve the structural and mechanical properties of the dough (Amiri et al., 2017). In addition to vitamin C, they also contain vitamins B, K, P, and pectin substances. Seeds contain oils rich in vitamin E (Murathan et al., 2016; Oliinyk et al., 2020; Olsson et al., 2005). Rosehips are important as food raw materials, containing a lot of fiber and other useful substances including relatively big amount (0.7-9.6 mg%) of β-carotene (Tertychnaya et al., 2020).

According to Gül et al. (2011), high fiber breads can be produced by incorporating rosehip seeds. Consumption may be increased by giving comprehensive information about the health benefits of these fiber enriched breads. Cvetković et al. (2009) also reported for effect of rosehip on dietary fiber content of bread. According to data, rosehip increased dietary fiber content in the supplemented bread for about 100%.

Boz et al. (2010) pointed out that rosehip in combination with other ingredients can be used as an improver to wheat dough. The combination of 0.5% Cephalaria and 2.5% rosehip significantly decreased the adhesion and stringiness of dough. Data showed that dough rheological characteristics of organic whole wheat flour could be improved with the addition of different materials such as malt flour, Cephalaria, rosehip and vital gluten.

Vartolomei et al. (2021) concluded that dough development time, dough stability, and softening degree vary significant, showing a combined influence of vitamin C provided by the rosehip powder, and the high fiber content. Moreover, the rosehip powder addition positively influenced the farinograph quality number.

Regarding the quality of bread, the samples prepared from wheat flour with the rosehip powder addition showed a significant increase in height, volume, specific volume, moisture, acidity, and porosity, as well as a slight decrease in elasticity as compared to the control bread (Vartolomei et al., 2021). Some authors indicated that, to ensure high bread quality, it is advisable to use the rosehip flour in an amount not more than 4% of the total mass of flour (Oliinyk et al., 2020). On the other hand, Sen (2013) concluded that the sensory profile of breads produced with 5% rosehip seed flour have been most liked after the control sample of bread.

Apart from being used as flour, rosehips can also be used in bread making as extracts. Rosehip extract was added when kneading the dough at doses of 5%, 10% and 15% (of flour weight), while the control sample of bread was without extract. When the additive was in the amount of 10%, the specific volume of bread was higher than in the control sample. According to sensory evaluation, the sample with 10% rosehip extract received the highest score (Pozdnyakova et al., 2019). Blinova et al. (2016) reported that the use of extract of rosehips (in an amount of 1.00% and 1.25%) in the production of bread from wheat flour improved its volume and crumb porosity.

The aim of research was to study the impact of rosehip flour added in amounts of 5, 10 and 15% to replace the equal amounts of the wheat flour on properties of wheat dough and bread.

Materials and methods

Materials

For the preparation of bread samples, the following materials were used:

- commercial wheat flour (type 500) (average chemical composition: fat 0.9g/100 g of which saturated 0.3 g; carbohydrates 70.3 g/100 g, of which sugars 3.4 g, fiber 4.0 g/100 g; protein 10.8 g/100 g);
- rosehip flour (average chemical composition: fat 0 g/100 g of which saturated 0 g; carbohydrates 38 g/100 g, of which sugars 3 g, fiber 24 g/100 g; protein 2 g/ 100 g);
- water – according to ISO 6107-1:2004;
- commercial yeast – supplied by Lesaffre Ltd. (Sofia, Bulgaria);
- salt – according to Codex Standard for Food Grade Salt CX STAN 150-1985.

Methods

Preparation of wheat dough and bread samples

Bread was obtained from type 500 wheat flour by a two-phase method. First, the yeast, part of the flour and water were mixed in a ratio of 1:1 in a dough kneading machine (Labomix 1000, Hungary). The control sample was made of wheat flour only, whereas the other samples of bread studied were prepared by adding rosehip flour to replace 5%, 10% or 15% of the wheat flour. The dough thus prepared rose for 60 min at 33°C and was then kneaded until obtaining a homogeneous texture by adding the remaining flour and water according to the recipe, plus salt (1.33 kg/ 100 kg of flour). The bread dough was divided into parts with a specified weight (440 g) and shaped, then left to rest for 60 minutes at 35°C for final fermentation (Tecnopast CRN 45–12, Novacel ROVIMPEX Novaledo, Italy). Then, the pieces of dough were baked in an electrical oven (Salva E-25, Spain) pre-heated to 220 – 230°C. Baking time was 24 min. After baking, the bread was left to cool down for 3 hours at room temperature.

The formulations of the studied samples of bread are presented in Table 1.

Gas formation properties of wheat flour

The gas-formation properties of wheat flour were determined by micro gas-meter, quantifying the gas formed in equal time intervals (15 min). The dough recipe was: flour, 5.0 g; yeast, 0.4 g; water, 3.0 ml. The dough sample fermented at 30°C for 150 min (Karadzhov et al., 1982).

Table 1

The formulations of bread samples (% on the flour basis)

Ingredients	Bread samples			
	Control sample (100% wheat flour)	with rosehip flour (%)		
		5	10	15
Wheat flour, g	450	427.5	405.0	382.5
Rosehip flour, g	–	22.5	45.0	67.5
Water, ml	248	248	248	248
Yeast, g	9.00	9.00	9.00	9.00
Salt, g	6.00	6.00	6.00	6.00

Color characteristics of the wheat dough

Color was evaluated in the crumb using a colorimeter „MOMCOLOR – D”. Color was measured on five different points on each sample, taking them in the central and outward parts of the loaf, avoiding its edges (Wricht, 1985). The following parameters were defined: Lightness (L); Color of saturation (D); Color tone (C).

Rheological properties of the wheat dough

The following dough characteristics were determined by a farinograph (Brabender GmbH&Co. KG, Duisburg, Germany): water absorption,%, development time, min, stability, min, degree of softening, farinograph units (FU), and consistency (FU), with AACC Method 54-21.02 (AACC, 2010).

Bread quality

Physical properties. Bread loaf volume was determined after baking and cooling the breads for 3 h at room temperature (20±2 °C) by a rapeseed displacement method (AACC, 2010). The specific volume was calculated by the ratio between volume, cm^3, and mass, g, of each sample. Bread height and diameter were measured by a calliper, and the shape stability (height/diameter) was calculated (Novotni et al., 2012). Bake loss,%, was determined weighing each loaf before and after baking (Kim et al., 2015).

Sensory analysis. Sensory analysis of the tested bread samples was performed by a panel consisting of 25 panelists (52% women and 48% men), who were familiar with sensory analysis of foods but not specifically trained in the evaluation of bread. The panelists were chosen using the following criteria: ages between 20 and 60, non-smokers, without reported cases of food allergies, bread consumers. The tests were performed in a laboratory with good ventilation and sufficient natural lighting. Each sample was labelled with a three-digit random code. The analysis was carried out according to ISO 6658:2017 (Sensory Analysis—Methodology—General Guidance). The panelists were asked to score seven parameters, namely appearance, crust color, crumb color, porosity, aroma, chewability and taste. The intensity of each attribute was presented on a 9-point scale (9, extremely good; 1, extremely bad).

Data analysis

All the tests were conducted with three replications. Data were analysed by one-way analysis of variance (ANOVA) using Statgraphics Centurion statistical program (version XVI, 2009) (Stat Point Technologies, Ins., Warrenton, VA, USA). To compare the means, Fisher's least significant difference test was used for paired comparison with a significance level α = 0.05.

Results and discussion

Effect of rosehip flour substitution on gas formation properties of wheat flour

The results regarding the intensity of gas formation of wheat flour (WF), rosehip flour and the samples in which part of the wheat flour (5%, 10% or 15%) was replaced by rosehip flour are presented in Figure 1. The values were measured using a micro gasometer.

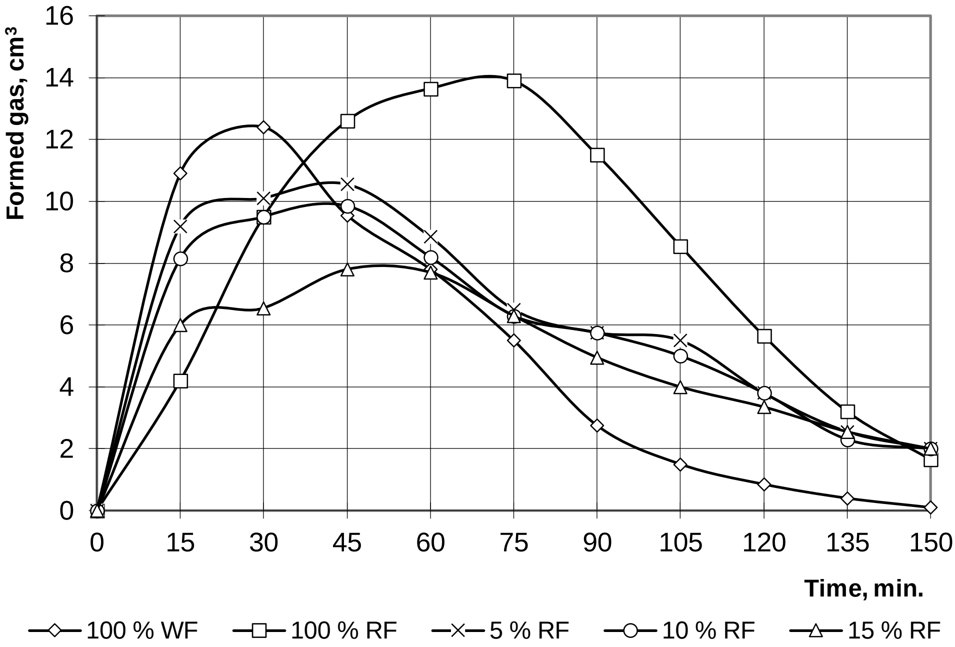


Figure 1. Intensity of gas formation of wheat flour (WF), rosehip flour (RF) and mixtures of wheat and rosehip flour

The amount of gas formed varied significantly depending on the raw materials. In the sample containing 100% wheat flour, the maximum amount of gas, 12.4 cm^3, was formed approximately 25-30 minutes after kneading. In the case of 100% rosehip flour, gas formation was more extensive, with a maximum reported amount of 13.9 cm^3, but this peak was reached after a longer period of time about 70 minutes after kneading. In both cases, however, gas formation followed a common trend - an increase in the amount, reaching a peak (although after a different time) and a sharp decrease in the intensity of gas formation.

As can be seen from the figure, different percentages of rosehip flour added (5%, 10% or 15%) resulted in lower gas formation intensity and smaller volumes of gas evolved were observed. The following dependence was established – the higher the amount of rosehip flour added, the lower the intensity of gas formation. In addition, all three samples had similar course of gas formation – a rise in the amount of gas formed after kneading, reaching a peak, an insignificant decrease, followed by a second peak, in which the maximum amount of gas formed was reached, followed by a decline.

At the beginning – up to the 40th minute after kneading, wheat flour had more intense gas formation than the mixtures containing rosehip flour. After that, there was a significant decline for the wheat flour, while the mixtures containing rosehip flour showed higher gas formation until the end of the measurement (150 minutes after kneading). According to Oliinyk et al. (2020), this might be associated with the strengthening of gluten of wheat flour due to the action of ascorbic acid. It is known that ascorbic acid, turning into dehydroascorbic acid in the dough, oxidizes the SH-groups of gluten proteins, proteolytic enzymes and proteolysis activators, thereby reducing the proteolysis intensity in the dough.

Total amount of the formed gas in wheat flour, rosehip flour and the samples where a part of the wheat flour (5%, 10% or 15%) was replaced by rosehip flour are presented in Figure 2.

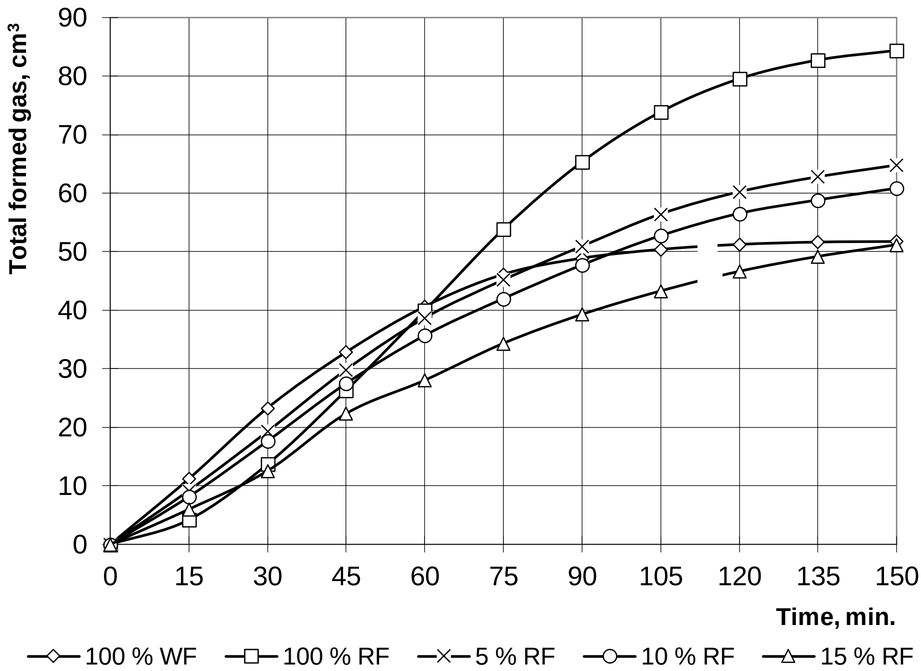


Figure 2. Total formed gas of wheat flour (WF), rosehip flour (RF) and mixtures of wheat and rosehip flour

It was found that rosehip flour formed the largest amount of gas of all the samples examined, 85 cm^3. For the wheat flour and mixtures with rosehip flour added, the curves are comparable with insignificant differences in the amount of gas released. However, the amount of gas decreased when the proportion of rosehip flour was increased. For the sample containing 5% rosehip flour, the total gas formed was 64 cm^3, for the sample with 10% rosehip flour, the result was 61 cm^3. When replacing 15% of the wheat flour with rosehip flour, a total of 51 cm^3 formed gas was found, which 20% was less than the sample with 5% rosehip flour. The figure clearly shows that when different types of flour were mixed in different ratios, gas formation differs. A study pointed out that the addition of rosehip powder in doses of 1-7% on the basis of wheat flour increased the amount of carbon dioxide, probably due to the high content of mono- and disaccharides. According to Lapytska (2020), this is due to the fact that adding rosehip flour to the dough enhances alcoholic fermentation, because of the stimulating effect of biologically active substances in the rosehip flour on the activity of the yeast. On the other hand, the introduction of rosehip flour at more than 5% on the basis of flour resulted into a loss of carbon dioxide due to the limited elasticity of the gluten framework (Kobilova et al., 2021).

Effect of rosehip flour addition on farinograph characteristics of wheat dough

Results concerning the effect of rosehip flour on the farinograph properties of dough are presented in Table 2.

Table 2

Effect of rosehip flour on the farinograph properties of dough

Samples	Water absorption (%)	Consistence (UB)	Dough development time (min)	Stability (min)	Degree of softening (UB)
Control sample (100% WF)	62.4 ± 0.14^a	500 ± 0.0^a	1.5 ± 0.0^a	7 ± 1.0^a	170 ± 3.61^a
Rosehip flour, 5%	61.2 ± 0.22^a	500 ± 0.0^a	1.5 ± 0.0^a	13 ± 2.0^b	110 ± 4.36^b
Rosehip flour, 10%	61.0 ± 0.44^b	520 ± 0.1^b	1.5 ± 0.0^a	9 ± 2.0^a	60 ± 3.05^c
Rosehip flour, 15%	60.8 ± 0.32^c	500 ± 0.0^a	1.5 ± 0.0^a	8 ± 2.0^a	50 ± 3.46^d

$^{a\text{-}d}$: Means in a column without a common letter differ significantly ($p < 0.05$).

Different authors (Amjid et al., 2013; Berton et al., 2002) reported that the hydration of the flour during kneading is of crucial importance for the dough properties and the quality of the bread. By increasing the amount (5%, 10% and 15%) of rosehip flour added, the farinograph properties of the wheat dough changed. A decrease in water absorption was established, and in the samples with 10% and 15% rosehip flour, the differences compared to the control sample were statistically significant. Gül and Şen (2017a) pointed out that by replacing gluten containing wheat flour with different ratios of rosehip flour, the interaction between water and fiber in the dough was restricted. In terms of dough development time and consistency, there were no differences between the tested samples, regardless of their composition. Vartolomei et al. (2021) found a slight variation in the dough development time when rosehip flour was added (in an amount from 0.5% to 2.5%), but the differences were not statistically significant. Other authors also reported variations in dough development time (Sudha et al., 2007). Smaller softening degree was reported for the fortified samples. Other authors, studying the same problem, concluded that fiber in rosehip flour fortified dough competed for water and delayed gluten development during mixing. Thus, a significant decrease at softening degrees of rosehip flour containing dough was observed.

According to Fu et al. (2008), dough stability time provides some indications regarding the tolerance of flour to mixing and kneading. Dough stability was found to be higher in the samples with the addition of rosehip flour, with the highest value reported for the sample with 5% rosehip flour. Other authors (Kohajdová et al., 2011; Nassar et al., 2008) also found an increase in dough stability time in samples fortified with fiber-rich additives explaining it through a higher interaction of fibres, water, and proteins in flour. Boz et al. (2010) reported that the use of rosehip with other ingredients in wheat dough could improve the dough rheological characteristics of whole wheat flour.

Effect of rosehip flour addition on color of wheat dough and bread

Color characteristics of the control sample of dough and the three formulations with rosehip flour added are presented in Table 3.

From the data presented in Table 3, it is clear that the addition of rosehip flour had a significant effect on the colour characteristics of the dough. The values of all three measured parameters (L, C and D) decreased with increasing the degree of replacement of wheat flour with rosehip flour. Dough brightness (L) had the highest value in the control sample. The addition of 5% rosehip flour resulted in a 15.7% decrease in the value, while at 15% the measured value was 31% lower than that of the wheat flour control sample. Darker colour of rosehip flour enriched samples could be due to the original colour of rosehip fibre, as pointed out by Gül and Şen (2017b), which is rather brown and slightly reddish. Dough colour tone (C) and dough saturation number (D) also differed most significantly from those of the control sample when the degree of replacement with rosehip flour was the highest, 15%.

Color characteristics of the control sample of bread and the three bread samples with rosehip flour added are presented in Table 4.

Table 3

Effect of rosehip flour on color characteristics of wheat dough

Samples	Dough brightness (L)	Dough color tone (C)	Dough saturation number (D)
Control sample (100% WF)	112.5±2.78^{a}	- 2.000±0.06^{a}	174.8±1.00^{a}
Rosehip flour, 5%	94.8±0.35^{b}	- 2.050±0.02^{b}	150.2±1.12^{b}
Rosehip flour, 10%	83.2±0.79^{c}	- 2.057±0.00^{c}	138.5±1.39^{c}
Rosehip flour, 15%	77.4±1.04^{d}	- 2.060±0.01^{c}	121.9±0.87^{d}

$^{a-d}$: Means in a column without a common letter differ significantly ($p < 0.05$).

Table 4

Effect of rosehip flour on color characteristics of wheat bread

Samples	Bread Brightness (L)	Bread Color tone (C)	Bread Saturation number (D)
Control sample (100% WF)	113.6±1.01^{a}	- 1.880±0.03^{a}	158.3±0.66^{a}
Rosehip flour, 5%	94.4±1.82^{b}	- 2.050±0.04^{b}	148.6±0.20^{b}
Rosehip flour, 10%	81.3±0.56^{c}	- 2.059±0.00^{c}	128.5±1.13^{c}
Rosehip flour, 15%	77.0±1.73^{d}	- 2.062±0.00c	115.3±0.72 ^{d}

$^{a-d}$: Means in a column without a common letter differ significantly ($p < 0.05$).

Different authors were studied the change in the colour of bread when additives had been included in the recipe. Erkan et al. (2006) concluded that instrumental measurement of baked products' colour was an inevitable quality check that could be used in determining the effects of ingredient or product formulation, process parameters and storage conditions on baked products. According to Callejo (2011), crumb color is highly related with ingredients (recipe). The use of flours, other than wheat, contributed to changes in the crumb color. Incorporation of rosehip flour decreased the brightness (L), colour tone (C) and bread saturation number (D) values which was most pronounced when 15% rosehip flour were included in the bread recipe. Increasing rosehip flour content led to the decrease in yellowness and resulted in the higher redness of bread crumb. This is due to the color of rosehip, which contain anthocyanins-compounds (Drożdż et al., 2014). A similar trend was found by Gül and Şen (2017b), who investigated the color characteristics of bread replacing 5%, 7.5% and 10% of wheat flour with rosehip flour. The results published by Boz et al. (2013), who studied the improvement of the quality of bread using different plant materials, are similar. They pointed out that the addition of rosehip flour decreased crumb L colour value. Therefore, crumb L colour value was lower in all samples containing rosehip. However, as mentioned by Gomez et al. (2003), the bread crumb colour is usually similar to the colour of the ingredients because during the baking the crumb does not reach as high temperatures as the crust.

Effect of rosehip flour substitution on physical properties of wheat bread

The results regarding the influence of added rosehip flour on the volume of bread are presented in Figure 3.

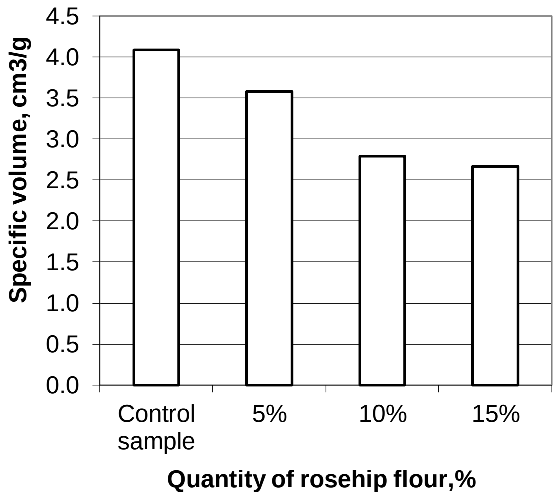


Figure 3. Effect of rosehip flour on the specific volume of wheat bread

Replacing part of the wheat flour with rosehip flour led to a change in the bread volume. The dependence between the amount of the additive and the change in the volume was pronounced. The highest volume was measured in the control sample (100% WF) – 1225 cm^3. The inclusion of 5% rosehip flour in the bread recipe caused a reduction in the volume by 13.5%. When 10% of the wheat flour were replaced by rosehip flour, the volume of the bread was 858.5 cm^3, which was 30% less than the control sample and 19% less than the sample with 5% rosehip flour. The most significant change in the bread volume was found with the inclusion of 15% rosehip flour – a reduction of 32% compared to the bread made from wheat flour only.

The specific volume varies from 4.09 cm^3/g (in the control sample of bread) to 2.67 cm^3/g (in the bread sample with 15% rosehip flour added). The control sample had the highest specific volume, and the more rosehip flour was included in the bread recipe, the denser it was. It was found that a high fibre content in rosehip flour dilutes gluten proteins during dough kneading, leading to a soft and inelastic dough. Thus, bread has a significantly smaller specific volume (Van Hung et al., 2007).

H/D index and baking loss of the tested samples of bread are presented in Table 5.

Table 5

Effect of rosehip flour on H/D index and baking loss of wheat bread

Samples	Height/Diameter	Bake loss,%
Control sample (100% WF)	0.60±0.01	11.04±0.08
Rosehip flour, 5%	0.55±0.01	10.60±0.03
Rosehip flour, 10%	0.56±0.02	9.89±0.08
Rosehip flour, 15%	0.57±0.01	9.44±0.04

The height/diameter ratio differed between the control and rosehip flour -supplemented samples. It is well known that bread volume correlates with the moisture of the dough. Thus, Gallagher et al. (2003) stated that higher moisture positively influences bread volume. A higher water absorption was already found for the control sample.

The average technological losses, on the other hand, changed slightly in a decreasing manner along with the increased percentage of rosehip flour. The values ranged from 11.04% for the control to 9.44% for the sample containing 15% rosehip flour. It can be assumed that rosehip flour retains water more firmly and the evaporation of water during the technological process was lower for the enriched samples.

Effect of rosehip flour substitution on sensory characteristics of wheat bread

The results obtained in the sensory analysis of wheat bread and breads enriched with rosehip flour (in the amount of 5, 10 and 15%) are presented in Figure 4.

The bread appearance is, for most consumers, one of the main criteria for evaluating the bread quality and is of great importance as a decision-making element of purchasing. In the present study, the bread samples with addition of rosehip flour differed in appearance from the control mainly by their lower height and volume. Moreover, there was a relationship between sensory and instrumental measured parameters. The scores, given by the panelists to the appearance of the control and rosehip flour substituted breads were in correlation with the values found for the instrumental measurements of the volume (Fig. 3), with decreasing values as the proportion of rosehip flour increased in the formulation. Similar results were also established by Gül and Şen (2017b). Van Hung et al. (2007) stated that the addition of fiber dilutes the proteins and prevents the formation of the optimal gluten network, explaining the decrease in bread volume when fiber-rich raw materials are added, such as rosehip flour.

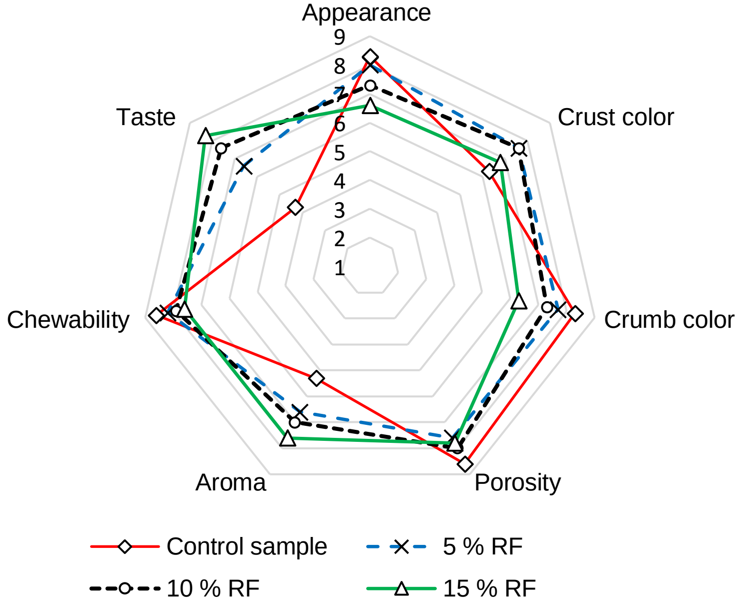


Figure 4. Effect of rosehip flour on sensory characteristics of bread.

Often, the color of bread is the first sensory characteristic perceived by the consumer, and color tends to influence consumer attitudes toward the product. The enriched bread samples had a more pronounced and more intense brown color of the crust, which increased as the amount of rosehip flour increased. The crust of the samples was thin, smooth and soft.

As the percentage of rosehip flour increased, the color of the bread crumb become darker and the whiteness decreased. This might be due to the high ash and anthocyanin content of rosehip flour. This accounted for the lower scores given by the panelists to the bread samples containing rosehip flour. There was a difference of almost 3 grades in the scores for the wheat bread and the bread with 15% rosehip flour added.

The control sample had smaller and evenly distributed pores and a higher porosity which was the reason for the higher scores given by the panelists. The porosity decreased with increasing the quantity of rosehip flour in the formulation. By comparing the samples containing rosehip flour with the control, it could be noted that rosehip flour had a positive influence on bread aroma which was most pronounced for the sample with 15% rosehip flour added. More than 30 aroma compounds were detected in the rosehip including terpenes, alcohols, esters, and aldehydes (Pashazadeh et al., 2021) which determined the stronger and much more pleasant aroma of the samples containing rosehip flour.

As pointed by Boz et al. (2013), chewiness is related to the effort needed to chew a solid sample, such as bread, to a steady state of swallowing. The crumb chewiness depends on the crumb firmness, cohesiveness and springiness. The highest chewiness value was determined for control sample (8.6), while a decreasing trend in the ratings of rosehip flour enriched samples was found. The scores range from 8.2 for the bread with 5% rosehip flour to 7.6 for the sample with 15% rosehip flour added.

The taste of the control sample was rated the lowest. The results showed that a higher amount of rosehip flour contributed to a much more pleasant taste and an increase in the scores given by the panelists. Rosehip flour contains a lot of substances with a pronounced taste (organic acids, phenolic compounds, and sugars) that determine its influence on the taste of wheat bread.

Other authors also studied the influence of rosehip flour on the sensory properties of bread and found that rosehip flour had a positive influence especially when used in low concentrations (up to 2%) (Ghendov-Mosanu et al., 2020). Kobilova et al. (2021) and Olsson et al. (2005) found that the addition of rosehip flour to the formulation favourably affected all sensory indicators of the finished products, especially taste, aroma and porosity.

Conclusions

1. The replacement of 5%, 10% or 15% of wheat flour with rosehip flour affected the intensity of gas formation: as the percentage of rosehip flour added increased, the intensity of gas formation decreased.
2. Incorporation of rosehip flour into wheat dough resulted in a decrease in water absorption and degree of softening. In terms of dough development time and consistency, there were no differences between the samples. Dough stability was found to be higher in the samples containing rosehip flour with the highest value reported for the sample with 5% rosehip flour added.
3. Dough and bread color characteristics (L, C and D) decreased with increasing the degree of replacement of wheat flour with rosehip flour in the range of 5 – 15%.
4. It was found that the substitution of wheat flour with rosehip flour at the amount of 5%, 10% or 15% resulted in a decrease in volume, specific volume, height/diameter ratio, and baking loss of the wheat bread.
5. Some of the sensory parameters of wheat bread, such as crust color, aroma and taste, in the bread with rosehip flour were rated higher by the panelists compared to the control sample, regardless of the amount of rosehip flour added.

Acknowledgment. Authors would like to thank to the Ministry of Education and Science of Bulgaria about the subsidy in accordance with the Ordinance on the Terms and Procedure for the Evaluation, Planning, Allocation and Expenses of the State Budget Funds for the Financing of the Inherent Research Activities of the State Higher Education Institutions. The acknowledgements are also to the academic management of University of Economics – Varna for the allocations in project NPI-55/2021 "Improving the quality and usefulness of food – trends and innovative practices (on the example of bread)".

References

AACC International. (2010), *AACC Approved Methods of Analysis, 11th ed.,* AACC International, St. Paul.

Amiri A., Shahedi M., Kadivar M. (2017), Structural properties of gluten modified by ascorbic acid and transglutaminase, *International Journal of Food Properties*, 20(2), pp. 1588–1599, DOI: 10.1080/10942912.2017.1349141.

Amjid M., Shehzad A., Hussain S., Shabbir M., Khan M., Shoaib M. (2013), A comprehensive review on wheat flour dough rheology, *Pakistan Journal of Food Sciences*, 23(2), pp. 105–123.

Berton B., Scher J., Villieras, F., Hardy J. (2002), Measurement of hydration capacity of wheat flour: Influence of composition and physical characteristics, *Powder Technology*, 128(2-3), pp. 326-331, DOI: 10.1016/S0032-5910(02)00168-7.

Bhave A., Schulzova V., Chmelarova H., Mrnka L., Hajslova J. (2017), Assessment of rosehips based on the content of their biologically active compounds, *Journal of Food and Drug Analysis*, 25(3), pp. 681–690, DOI: 10.1016/j.jfda.2016.12.019.

Blinova O., Prazdnichkova N., Trots A., Makushin A. (2016), The use of syrop from hips in the production of bread from wheat flour, *Modern Science Success*, 3(1), pp. 45–47.

Böhm, V., Fröhlich K., Bitsch R. (2003), Rosehip – a "new" source of lycopene? *Molecular Aspects of Medicine*, 24, pp. 385–389, DOI: 10.1016/S0098-2997(03)00034-7.

Boz H., Karaoğlu M., Kotancilar H., Gerçekaslan K. (2010), The effects of different materials as dough improvers for organic whole wheat bread, *International Journal of Food Science & Technology*, 45(7), pp. 1472–1477, DOI: 10.1111/j.1365-2621.2010.02289.x.

Boz H., Karaoğlu M. (2013), Improving the quality of whole wheat bread by using various plant origin materials, *Czech Journal of Food Sciences*, 31(5), pp. 457–466, DOI: 10.17221/410/2012-CJFS.

Callejo M. (2011), Present situation on the descriptive sensory analysis of bread, *Journal of Sensory Studies*, 26(4), pp. 255–268, DOI: 10.1111/j.1745-459X.2011.00341.x.

Cvetković B., Filipčev B., Bodroža-Solarov M., Bardić Ž., Sakač M. (2009), Chemical composition of dried fruits as a value added ingredient in bakery product, *Food Processing, Quality and Safety*, 36(1–2), pp. 15–20.

Demir F., Özcan M. (2001), Chemical and technological properties of rose (*Rosa canina* L.) fruits grown wild in Turkey, *Journal of Food Engineering*, 47, pp. 333–336, DOI: 10.1016/S0260-8774(00)00129-1.

Drożdż W., Tomaszewska-Ciosk E., Zdybel E., Boruczkowska H., Boruczkowski T., Regiec P. (2014), Effect of apple and rosehip pomaces on colour, total phenolics and antioxidant activity of corn extruded snacks, *Polish Journal of Chemical Technology*, 16(3), pp. 7–11, DOI: 10.2478/pjct-2014-0042.

Erkan H., Celik S., Bilgi B., Koskel H. (2006), A new approach for the utilization of barley in food products: barley tarhana, *Food Chemistry*, 97(1), pp. 12–18.

Ercisli S. (2007), Chemical composition of fruits in some rose (*Rosa spp.*) species, *Food Chemistry*, 104, pp. 1379–1384, DOI: 10.1016/j.foodchem.2007.01.053.

Fu L., Tian J.-C., Sun C.-L., Li C. (2008), RVA and farinograph properties study on blends of resistant starch and wheat flour, *Agricultural Sciences in China*, 7(7), pp. 812–822, DOI: 10.1016/S1671-2927(08)60118-2.

Gallagher E., Kunkel A., Gormley T., Arendt E. (2003), The effect of dairy and rice powder addition on loaf and crumb characteristics, and on shelf life (intermediate and long-term) of gluten-free breads stored in a modified atmosphere, *European Food Research and Technology*, 218, pp. 44–48, DOI: 10.1007/s00217-003-0818-9.

Ghendov-Mosanu A., Cristea E., Patras A., Sturza R., Niculaua M. (2020), Rose Hips, a Valuable Source of Antioxidants to Improve Gingerbread Characteristics, *Molecules*, 25(5659), pp. 10–18, DOI: 10.3390/molecules25235659.

Gomez M., Ronda F., Blanco C., Caballero P., Apesteguia A. (2003), Effect of dietary fiber on dough rheology and bread quality, *European Food Research and Technology*, 216, pp. 51–56, DOI: 10.1007/s00217-002-0632-9.

Gül H., Gül M. (2011), High fiber bread consumption and consumers' awareness: a case study from Isparta, *Proceedings of the International Food Congress Novel Approaches in Food Industry*, May 26-29, Çeşme, Izmir, Turkey, p. 899.

Gül H., Şen H. (2017a), Effects of rosehip seed flour on the rheological properties of bread dough, *Scientific Bulletin. Series F. Biotechnologies*, 21, pp. 330–335.

Gül H., Şen H. (2017b), The influence of rosehip seed flour on bread quality, *Scientific Bulletin. Series F. Biotechnologies*, 21, pp. 336–342.

ISO 6658:2017 (2017), *Sensory Analysis–Methodology–General Guidance*, ISO, Geneva.

Kaiyun L. (2016), *Eye-Protecting Anti-Radiation Pineapple Bread and Preparation Method*, Thereof. Patent CN 105341087 A.

Karadzhov G., Vangelov A. (1982), Apparatus for determining the gas-forming properties of flour, *Scientific Works of Higher Institute of Food Industry – Plovdiv*, 29(1).

Kim W., Lee G. (2015), Comparison of imported wheat flour bread making properties and korean wheat flour bread making properties made by various bread making methods, *Journal of Korean Society of Food Science and Nutrition*, 44(3), pp. 434–441, DOI: 10.3746/jkfn.2015.44.3.434.

Kobilova N., Raxmatov E., Shomuradova N., Murtazaevave K. (2021), Research of the influence of powders from rosehips from rosehips on indicators of national peels, *Journal for Innovative Development in Pharmaceutical and Technical Science*, pp. 171–173.

Kohajdová Z., Karoviˇcová J., Jurasová M., Kukurová K. (2011), Effect of the addition of commercial apple fibre powder on the baking and sensory properties of cookies, *Acta Chimica Slovaca*, 4, pp. 88–97.

Murathan Z., Zarifikhosroshahi M., Kafkas E. (2016), Determination of fatty acids and volatile compounds in fruits of rosehip (*Rosa* L.) species by HS-SPME/GC-MS and Im-SPME/GC-MS techniques, *Turkish Journal of Agriculture and Forestry*, 40(2), pp. 269–279.

Nassar A., Abdel-Hamied A., El-Naggar E. (2008), Effect of citrus by-products flour incorporation on chemical, rheological and organoleptic characteristics of biscuits, *World Journal of Agricultural Sciences*, 4, pp. 612–616.

Novotni D., Cukelj N., Smerdel B., Bituh M., Dujmi´c F., Ćurić D. (2012), Glycemic index and firming kinetics of partially baked frozen gluten-free bread with sourdough, *Journal of Cereal Science*, 55(2), pp. 120–125, DOI: 10.1016/j.jcs.2011.10.008.

Oliinyk S., Samokhvalova O., Lapitska N., Kucheruk Z. (2020), Studying the influence of meals from wheat and oat germs, and rose hips, on the formation of quality of rye-wheat dough and bread, *Eastern-European Journal of Enterprise Technologies*, 1, pp. 59–65, DOI: 10.15587/1729-4061.2020.187944.

Olsson M., Andersson S., Werlemark G., Uggla M., Gustavsson K. (2005), Carotenoids and phenolics in rose hips, *Acta Horticulturae*, 690, pp. 249–253, DOI: 10.17660/ActaHortic.2005.690.38.

Paredes-López O., Cervantes-Ceja M. L., Vigna-Pérez M., Hernández-Pérez T. (2010), Berries: improving human health and healthy aging, and promoting quality life—A review, *Plant Foods for Human Nutrition*, 65(3), pp. 299–308, doi:10.1007/s11130-010-0177-1.

Pashazadeh H., Ozdemir N., Zannou O., Koca I. (2021), Antioxidant capacity, phytochemical compounds, and volatile compounds related to aromatic property of vinegar produced from black rosehip (*Rosa pimpinellifolia* L.) juice, *Food Bioscience*, 44, pp. 1–10, DOI: 10.1016/j.lwt.2021.112716.

Pozdnyakova O., Zakharenko M., Nazimova E., Romanov A. (2019), Technological aspects of obtaining extract from rose hips and its use in bread production, *Achievements of Science and Technology in Agro-Industrial Complex*, 12, pp. 102–106.

Stabnikova O., Marinin A., Stabnikov V. (2021), Main trends in application of novel natural additives for food production, *Ukrainian Food Journal*, 10(3), pp. 524–551, DOI: 10.24263/2304-974X-2021-10-3-8.

Sudha M., Baskaran V., Leelavathi K. (2007), Apple pomace as a source of dietary fiber and polyphenols and its effect on the rheological characteristics and cake making, *Food Chemistry*, 104(2), pp. 686–692, DOI: 10.1016/j.foodchem.2006.12.016.

Tertychnaya T., Mazhulina I., Vysotskaya E., Andrianov E., Glotova I. (2020), New formulas of muffins of functional purpose with rosehip and broccoli, *Journal of Critical Reviews*, 7(9), pp. 1732–1740, DOI: 10.31838/jcr.07.09.309.

Van Hung P., Maeda T., Morita N. (2007), Dough and bread qualities of flours with whole waxy wheat flour substitution, *Food Research International*, 40(2), pp. 273–279, DOI: 10.1016/j.foodres.2006.10.007.

Vartolomei H., Turtoi M. (2021), The influence of the addition of rosehip powder to wheat flour on the dough farinographic properties and bread physico-chemical characteristics, *Applied Science*, 11(24), 12035, DOI: 10.3390/app112412035.

Wricht W. (1985), *The measurement of colour*, Bilger Hatto, London.

Use of lupine flour and cavbuz puree in bread technology

Svitlana Bazhay-Zhezherun, Galina Simakhina, Ludmyla Bereza-Kindzerska, Tetiana Romanovska

National University of Food Technologies, Kyiv, Ukraine

Keywords:

Cavbuz
Lupine
Flour
Bread
Health food

Article history:

Received 15.07.2022
Received in revised form 19.11.2022
Accepted 30.12.2022

Corresponding author:

Svitlana Bazhay-Zhezherun
E-mail: LanaNEW_1@ukr.net

DOI: 10.24263/2304-974X-2022-11-4-7

Abstract

Introduction. The influence of vegetable additives: cavbuz (a hybrid of watermelon and pumpkin) puree and flour of non–alkaloid lupine on the nutritional and biological value of wheat bread, its sorption capacity in relation to toxic lead ions was studied.

Materials and methods. Content of following substances was determined: proteint by Bradford method; starch by polarimetric method; fat by exhaustive extraction with chemically pure hexane; vitamins E, P (rutin), β–carotene colorimetrically; vitamin C titrimetrically; B_1, B_2 fluorometrically; fiber by acid hydrolysis; pectin by the calcium–pectate method; te amount of lead absorbed by “wet burning” method.

Results and discussion. Cavbuz puree is a rich source of substances with antioxidant activity: β-carotene, 13.4 mg, P (rutin), 45.4 mg, phenolic compounds, 283.23 mg, as well as natural food sorbents such as fiber 1.7% and pectin, 1.5% per 100 g of product with moisture content 83.1%. According to sensory and physico-chemical characteristics, cavbuz puree may be used as a component in the manufacturing of health products. Lupine flour contains 3.9 times more protein, 40 times more fiber, 10.5 pectin substances compared to wheat flour; a significant amount of tocopherols, 12.8 mg, β-carotene, 0.52 mg, vitamin C, 35.84 mg per 100 g of product with moisture content 9.5%.

The inclusion of 4-7% of lupine flour and 3–5% of cavbus puree in the recipe of wheat bread, makes it possible to obtain bread for health purposes, in which the protein content is 22–32%, fiber content is two to three times higher, tocopherols are 9 times higher than in control, provided that the physico-chemical and organoleptic parameters of the product are acceptable. 100 g of developed bread provides 23% of the minimum rate of pectin consumption, 6% of the daily need for vitamin E; 13.8% in B_1, 14% in β–carotene; 6.6% in flavonoids, which are absent in wheat bread. Enriched bread has a 25–30 times higher sorption capacity for toxic divalent lead ions than wheat bread.

Conclusions. It is recommended to use of cavbuz puree and flour of non–alkaloid lupine varieties for the production of wheat bread with increased nutritional value.

Introduction

Proteins play an extremely important role in human nutrition, as they are the main component of all organs and tissues of the body. It is also important to have a sufficient amount of dietary fiber in the diet, which has sorption properties in relation to toxic compounds, has a positive effect on the intestinal microbiome, and helps to prevent a number of metabolic diseases (Ioniță-Mîndrican et al., 2022). The need to increase the content of full–fledged proteins and natural food sorbents in the diet of the population (Hertzler et al., 2020) determines the feasibility of enriching mass consumption products with these compounds, in particular bread and bakery products.

Lupine, along with soy, has the highest content of full protein among legumes, contains biologically active substances, such as oligosaccharides, phenolic compounds and vitamins, which have a wide range of biological effects: they participate in redox processes, are natural antioxidants, and precursors of coenzymes (Ruiz-Lópezet et al., 2019). Promising for use in the food industry are new varieties of narrow-leaved, alkaloid-free lupine, which contain 36–40% of proteins, 6–6.5% of fat, 26% of carbohydrates, but have a rather insignificant content of alkaloids, 0.0025%, compared to yellow and white lupine varieties (Ratoshniuk et al., 2020). Lupine flour, as well as protein concentrates and lupine isolates, which have a protein solubility of more than 90%, a water absorption capacity of 4.5 g/g of dry weight, are used to increase the protein content of pasta, bread, cookies, and as a gluten-free raw material in production dietary, functional and medical food products (Carvajal-Larenas et al., 2016; Krawęcka et al., 2022; Mazur, et al., 2018). A decrease in the density of bread and insignificant change in its elasticity and sensory indicators were observed in cases when lupine flour was included in the recipes (Guiné et al., 2015). Moreover, the amount of it in the recipe 5–15% contributes to increasing water absorption, improving the amino acid and fat-acid composition, as well as the content of mineral compounds (Hanan, 2013; Maghaydah et al., 2022). However, replacing wheat flour with lupine flour more than 10%, reduces the quality of bread, in particular porosity, elasticity, and increases stickiness (Lazdauskienė et al., 2022; Villarino et al., 2016). Therefore, it is actial to study the combination of the use of high-protein raw materials and food fiber sources for the enrichment of bread.

An important direction for the enrichment of bread products is also the use of vegetable purees (Ebrahimi et al., 2020). Adding vegetable purees to the recipe composition of bread significantly improves the quality of raw gluten, increases its sensory and nutritional properties (Amoah et al., 2021), increases the content of phenolic compounds and folic acid in finished products (Czarnowska-Kujawska, 2022). There is data on the use of pumpkin puree (Bayramov et al., 2022) and sweet potato puree (Malavi et al., 2022) for the enrichment of bread with bioavailable phenols, β-carotene, and fiber. The use of vegetable purees as sources of dietary fibers, which are sorbents of such heavy metals as lead cations, cadmium (Guo, 2022) in the technology of mass consumption products and, in particular, bread, is an urgent issue, weighing the distribution of these toxicants, particularly lead in the environment (Collin et al., 2022). Complex use of two enrichment agents: wheat germ and vegetable puree (Ebrahimi et al. 2020); sweet corn flours and drum-dried pumpkin (Amoah et al. 2021) in bread technology, improves nutritional value, increases antioxidant and sorption capacity of products.

A promising vegetable raw material is cavbuz, a molecular hybrid of watermelon and pumpkin, which contains a significant amount of pectin, sugars (glucose, fructose); hemicellulose, fiber, β-carotene, vitamins of group B, C, E, P; salts of potassium, calcium, magnesium, iron (Potopalskyi et al., 2019). The given research results prove that lupine flour could be used in bakery for increasing the protein content in products. There is also data on the independent use of vegetable purees and in combination with other non-traditional raw materials to enrich bread with vitamins, phenols, and natural sorbents. However, there are no studies on the possibility of using two natural enrichers: vegetable cavbuz puree and lupine flour for the production of healthy bread.

a b

Figure 1. Images of cavbuz (a) and lupine (b)

The aim of the present study is to check the feasibility of using lupine flour and cavbuz puree as a source of antioxidant compounds and natural sorbents to increase the nutritional value of wheat bread and increase its sorption capacity.

Materials and methods

Materials

During experimental studies, non-alkaloid lupine of the «Volodymyr» variety harvest 2021 (Mazur et al., 2018) and cavbuz varieties «Zdoruyaga» (Potopalskyi et al., 2019), samples of bread were used.

Methods

Preparation of puree

Preparation of cavbuz puree included washing of raw material, cleaning, removal of seed, slicing, blanching, wiping, homogenization, pasteurization, and packaging followed by storage at a temperature of 2–4 ° C, 2–3 days, or at a temperature of -18 to -22 ° C for 5–6 months.

The purified cavbus pulp was cut into pieces of 8–12 mm, blanched with hot steam at a temperature of 96–98 °C for 5–8 min. Then the mass was wiped through a sieve with a diameter of 0.7–0.8 mm, homogenization of the puree was carried out with a blender at a speed of 15000 rpm. The product was pasteurized at a temperature of 90 °C for 10 min.

Preparation of bread

The dough was kneaded in a non-evaporating manner (Drobot, 2019) from wheat flour of the first grade with partially replacemtn of flour with equal amount of non-alkaloid lupine, 4–8%, and cavbus puree, 2–6%. Yeast and salt were added in an amount of 1–1.5% of the flour weight. The developed formulations are given in Table 1.

Table 1

Dough preparation

№	Prescription components,%				
	First grade wheat flour	**Lupine flour**	**Cavbuz puree**	**Yeast**	**Salt**
1 (Control)	97	–	–	1.5	1.5
2	92	4.0	2.0	1.0	1.0
3	90	5.0	3.0	1.0	1.0
4	87	6.0	4.0	1.5	1.5
5	85	7.0	5.0	1.5	1.5
6	83	8.0	6.0	1.5	1.5

Titrated acidity. Titrated acidity in semi–finished products (dough) and finished products (bread) was determined by titration (Tyl et al., 2017).

Physical and chemical indicators of bread. The porosity of the bread was determined using the Zhuravlev device. Specific volume was determined by standard method (Drobot, 2019).

Moisture. The moisture content in the test samples was determined by drying to a constant mass at a temperature of 105 °C.

Protein. The protein content in the experimental samples was determined by the Bradford method (Carlsson et al., 2011).

Starch. The amount of starch was determined by the polarimetric method (Subroto et al., 2020).

Fat was determined by exhaustive extraction with chemically pure hexane (Erickson, 2005).

Vitamin E was determined by a method based on the formation of quinones during the oxidation of tocopherol molecules extracted from the test product by chloric iron. Chlorine iron is reduced to chloride, the amount of which is determined by the intensity of color during the addition of orthophenanthroline (Gamna, 2021).

β-carotene was determined by spectrophotometric method (Biehler et al., 2009).

Vitamin P **(rutin)** was determined by spectrophotometric method (Dong et al., 2020).

Phenolic compounds were determined by spectrophotometric method (Waterhouse, 2002).

Vitamin C content was determined by titrometric method, which is based on extraction of vitamin C from the test sample with a solution of acid (hydrochloric, metaphosphoric or a mixture of acetic and metaphosphoric) followed by titration visually or potentiometrically with a solution of 2,6–dichlorophenoline sodium phenolate (Majidi et al., 2016)

Choline was determined by a method based on the formation of a stained choline compound with Reinecke salt (Phillips, 2012)

Thiamine, riboflavin. Vitamin B_1 and B_2 contents were determined fluorometrically (Zajicek et al., 2005).

Polysaccharides. The fiber content was determined by acid hydrolysis (Möller et al., 2008). To determine the mass fraction of pectin substances, a weight calcium–pectate method was used, which is based on the hydrolysis of pectin substances to pectin acids, their precipitation in the form of calcium salts, drying and weighting (Chandel et al., 2022).

Determination of lead ion content. A sample of a water-acid solution of a bread sample containing pectin was prepared. For this purpose, the sample was hydrolyzed with distilled water at a temperature of 45°C for 30 minutes. The obtained extract was filtered. The bread residue was subjected to acid hydrolysis with HCl solution (0.3 mol/dm3) for 30 minutes in a boiling water bath to extract protopectin and pectic acid. The resulting solution was filtered. Filtrates of hydrated pectin and protopectin solutions were combined. The filtrate sample was treated with a standard lead solution (0.035 N) to form a precipitate of lead Pb pectates. The precipitate was boiled for 2 hours in a combustible mixture of concentrated nitric acid and a 30% hydrogen peroxide solution in a ratio of 3:1 to a clear solution. The content of lead ions in the solution was determined by spectrophotometric method (Lang et al., 2008).

Results and discussion

Chemical composition of the cavbuz

Chemical composition of raw materials is a factor influencing the quality of the finished product. The content of important macro- and micronutrients of cavbus in comparison with pumpkin is shown in Table 2.

The obtained results correlate with the data of Potopalskyi et al. (2019) and show that cavbus has a higher nutritional value in comparison with pumpkin, in particular, in the content of vitamins, sugars, pectin substances, and fiber.

Physico-chemical and sensory characteristics of vegetable puree quality

The physico-chemical and sensory characteristics of quality of cavbuz puree, given in comparison with pumpkin puree, were determined (Tables 3, 4).

Table 2

Chemical compositions of cavbus and pumpkin

Indicators	Value	
	Cavbus	Pumpkin
Dry matter content,%	16.9±0.2	8.8±0.2
Protein,%	0.60±0.01	0.51±0.02
Fat,%	0.05±0.12	0.06±0.01
Sugars,%	11.50±0.25	5.2±0.14
Pectin,%	1.63±0.02	0.7±0.12
Fiber ,%	1.85±0.11	1.2±0.15
Organic acids,%	0.1±0.1	0.1±0.1
Vitamins		
Vitamin E, mg/100 g	1.22±0.01	0.60±0.02
β–carotene, mg/100 g	18.53±0.12	10.14±0.43
Vitamin C, mg/100 g	37.52±0.03	10.36±0.02
P (rutin), mg/100 g	67.41±0.26	55.84±0.32
Choline, mg/100 g	84.2±0.34	75.3±0.38
Phenolic compounds, mg/100 g	328.12±0.42	285.24±0.35

Table 3

Sensory characteristics of puree

Parameters	Characteristics	
	Cavbuz puree	Pumpkin puree
Appearance	Grated homogeneous mass, without skin, fibers, seeds, seeds.	
Color	Saturated orange, homogeneous throughout the mass of cavbuz puree.	Yellow, homogeneous throughout the mass of puree
Smell	Peculiar to cavbuz, without foreign odors.	Characteristic of pumpkin, without extraneous odors.
Taste	Pleasant sweet, peculiar to cavbuz.	Sweet, peculiar to pumpkin.
Consistency	Homogeneous, without stratification, juicy without extraneous inclusions.	

Table 4

Physico–chemical characteristics of vegetable puree

Indicators	Cavbuz puree	Pumpkin puree
Dry matter content,%	15.32±0.12	7.23±0.31
Titrated acid content (in terms of malic acid),%	0.09±0.01	0.09±0.01
pH	5.6	5.2

Cavbus puree contains twice as much dry matter as pumpkin puree, both puree contain a small amount of organic acids.

It was noted that due to the presence of a significant amount of pectin substances and fiber, which are characterized by high water absorption capacity (Tan et al., 2017), cavbus puree has a thicker consistency, compared to pumpkin puree. During processing in the finished product, the content of vitamins decreases compared to the initial raw materials (Herrera-Ardila et al., 2022). The vitamin contents of vegetable puree, as well as the content of polysaccharides in them, which are part of the complex of food fibers, were determined (Table 5).

Table 5

Content of vitamins and polysaccharides in puree

Indicators	Content	
	Cavbuz puree	Pumpkin puree
Vitamin E, mg/100 g	0.92±0.03	0.34±0.02
β–carotene, mg/100 g	13.42±0.13	6.38±0.04
P (rutin), mg/100 g	45.42±0.22	36.41±0.31
Phenolic compounds, mg/100 g	283.23±0.25	236.81±0.15
Pectin,%	1.50±0.02	0.56±0.04
Fiber ,%	1.72±0.04	0.95±0.12

According to the results, cavbus puree has a higher content of vitamins, phenolic compounds, pectin, and fiber compared to pumpkin puree.

Nutritional value of wheat and non–alkaloid lupine flour

Comparison of the nutritional value of wheat and non-alkaloid lupine flour was done and the results are shown in Table 6.

Table 6

Chemical composition of flour

Indicator	Lupine flour	First grade wheat flour
Moisture,%	9.5±0.2	11.5±0.3
Proteins,%	41.87±0.12	10.82±0.24
Fats,%	11.03±0.14	1.28±0.05
Starch,%	4.51±0.06	72.04±0.12
Fiber,%	12.51±0.05	0.30±0.03
Pectin,%	10.52±0.36	–
Total ash content,%	2.42±0.15	0.70±0.03
Vitamins		
E, mg/100 g	12.82±0.03	0.21±0.1
β–carotene mg/100 g	0.52±0.02	0.11±0.01
C, mg/100 g	35.84±0.13	2.60±0.05
B_1, mg/100 g	0.22±0.01	0.18±0.01
B_2 , mg/100 g	0.11±0.01	0.15±0.01
P, mg/100 g	0.31±0.01	3.52±0.02

It is found that lupine flour contains four times more protein and more than ten times more fiber and pectin substances, and much more lipids compared to wheat flour. The amount of vitamins, in particular, tocopherols, β–carotene, B_1, is also much higher in lupine flour (Table 6). The results are similar with the data of scientists (Guiné et al., 2015; Prusinski et al., 2019).

Physico–chemical characteristics of dough and bread

Physico-chemical quality indicators of dough and wheat bread, as well as bread enriched with lupine flour and puree cavbus are given in Table 7.

Table 7

Physico–chemical characteristics of dough and bread

Indicators	Recipe number					
	1	**2**	**3**	**4**	**5**	**6**
Dough						
Mass fraction of moisture,%	44.0±0.3	43.9±0.1	43.5±0.2	43.2±0.2	42.9±0.1	42.8±0.3
Titrated acidity, degrees initial final	 2.2±0.2 2.5±0.1	 2.5±0.1 2.8±0.2	 2.7±0.1 3.1±0.1	 3.0±0.2 3.3±0.1	 3.1±0.1 3.5±0.1	 3.2±0.3 3.6±0.2
Bread						
Mass fraction of moisture,%	43.5±0.4	42.9±0.1	42.8±0.2	42.6±0.1	42.4±0.3	42.1±0.2
Acidity, degrees	2.7±0.2	3.0±0.1	3.0±0.1	3.1±0.2	3.2±0.1	3.3±0.3
Specific volume, cm^3/g	2.93±0.05	2.90±0.01	2.86±0.03	2.82±0.01	2.80±0.02	2.76±0.05
Porosity,%	71.0±0.2	71.5±0.3	70.2±0.1	69.5±0.4	68.6±0.2	66.2±0.4

The acidity of the dough and, accordingly, of ready–made products with the addition of lupine flour and cavbuz puree varied within 0.5–1.0 deg. When adding of plant enriches to the wheat bread recipe, the specific volume of products is slightly reduced by 1.1–4.5%, depending on the amount of additives. A decrease in specific volume by 5% and porosity of products by 4% was noted when lupin flour was added to the bread recipe in an amount of 10% (Villarino et al., 2016). Increasing the mass fraction of lupine flour to 8% and cavbuz puree to 6% prolongs the time of dough formation, worsens the form resistance of semi–finished products, the finished bread has a lower volume, the porosity structure is fine; since the high water–binding capacity of lupine dietary fibers weakens the gluten matrix, which affects the volume of bread (Guiné et al., 2015).

Effect of vegetable additives on the nutritional value and sensory properties of wheat bread

Characteristics of wheat bread prepared according to recipes shown in Table 1 are given in Table 8.

Table 8

Characteristics of wheat bread with vegetable additives

Recipe number	Content, %					Sensory indicators of bread
	Proteins	Fats	Starch	Fiber	Pectin	
1	7.92 ±0.50	1.21 ±0.23	47.52 ±0.24	0.30 ±0.12	–	The shape is correct, the surface is smooth without cracks, the pulp is well developed, the average porosity, the color is yellow, the taste and smell are inherent in wheat bread.
2	9.63 ±0.21	1.80 ±0.13	45.33 ±0.19	0.62 ±0.08	0.29 ±0.05	The shape is correct, the surface of the smooth pulp is well developed, the average porosity, the color is yellow, the taste and smell are inherent in wheat bread.
3	9.82 ±0.11	1.92 ±0.11	43.50 ±0.31	0.71 ±0.20	0.38 ±0.01	The shape is correct, the surface of the smooth pulp is well developed, the average porosity, the color is rich yellow, the taste and smell are pleasant, with a slight nutty tint.
4	10.20 ±0.22	2.00 ±0.24	41.24 ±0.12	0.80 ±0.14	0.46 ±0.04	The shape is correct, the surface is smooth, the pulp is well developed, the average porosity, the color is golden, the taste and smell are pleasant, with a nutty tint.
5	10.51 ±0.13	2.13 ±0.21	40.91 ±0.17	0.89 ±0.05	0.55 ±0.03	The shape is correct, the surface is smooth, the average porosity, the color is golden, the taste and smell are pleasant, with a walnut–vegetable tint.
6	10.85 ±0.32	2.22 ±0.30	38.17 ±0.26	0.96 ±0.26	0.64 ±0.04	The shape is correct, the surface with minor cracks, the pulp is well developed, small porosity, the color of the product is yellow, the taste of the vegetable additive is too pronounced.

In the production of bread with the introduction of lupine flour in the amount of 4–7% and puree cavbuz in the amounts of 2–5% to replace the equal amounts of the wheat flour, there are improvements in the structural and mechanical properties of the dough due to an increase in its water absorption capacity (Ratoshniuk et al., 2020). The process of dough formation is accelerated, and its blurring is reduced. Sensory characteristics of the finished product are acceptable: the shape of the bread is correct, the surface is smooth without cracks, the softness is well developed, the average porosity, the color of the product is golden, the taste and smell are pleasant, inherent in wheat bread. In the bread obtained according to the recipe 6, too pronounced taste of the vegetable additive in the finished product is noted, which is not appropriate.

Natural dyes found in vegetable additives, carotenoids and flavonoids (Ruiz–López et al., 2019; Saccotelli et al., 2018), contribute to the improvement of the sensory properties of the product, in particular, to intensify the color of bread.

The presence of increased amounts of protein substances in bread enriched with lupine flour and cavbuz puree, and gamma–conglutin, specific protein fraction of lupine, as well as dietary fibers, makes it possible to predict the positive physiological effects of this product in the human body. Foods enriched with fiber and protein play a significant role in the nutrition of individuals suffering from chronic cardiovascular diseases and excess weight (Belski et al., 2012).

The presence of lupine flour in this type of bread has important effects, since this raw material contains valuable biologically active compounds, namely, essential amino acids, vitamins, phenols (Prusinski et al., 2017) and, dietary fibers (Krawęcka et al., 2022). Using whole lupine and its processing products as part of food products, has more sustainable beneficial effects for saturation, glycemic control and blood pressure than extracted lupine protein or lupine fiber (Bryant et al., 2022).

The nutritional value of wheat bread and wheat bread, enriched with cavbuz puree and lupine flour was determined by the presence of essential food components. In addition, an important indicator characterizing nutritional value is the degree of provision of the human body in a certain nutrient, according to the recommended daily norm of consumption. The nutritional value of the developed bread (recipe 4) and control sample (recipe 1), as well as the results of calculating the degree of ensuring a person's daily need for important physiological and functional ingredients due to consumption of 100 g, are given in Table 9. For the calculation, the category of the population of the 1st intensity group aged 40–59 years (women) was selected.

Table 9

Food and energy value of bread enriched with lupine flour and cavbuz puree

Indicator	**Daily norms consumption**	**Nutrient content in 100 g of wheat bread**		**Provision daily norm,%,**	
		Control	Bread enriched with cavbuz puree and lupine flour	Control	Bread enriched with cavbuz puree and lupine flour
Proteins, g	58.0	7.9	10.2	13.6	17.6
Fats, g	58.0	1.2	2.0	2.1	3.4
Carbohydrates, g	240.0	47.5	41.2	19.8	17.2
Alimentary fiber, g	20.0	0.3	1.26	1.5	6.3
B_1, mg	1.3	0.16	0.18	12.3	13.8
B_2, mg	1.6	0.06	0.06	3.8	3.8
E, mg	15.0	0.1	0.90	0.7	6.0
β–carotene, mg	5.0	-	0.71	-	14.0
Flavonoids, mg	250.0	-	16.4	-	6.6
Energy value, kcal	1800	233.5	228.6	13.0	12.7

The enrichment of wheat bread with lupin flour and cavbuz puree increases the protein content in the new bread by 29.1%, dietary fiber by 4.2 times, compared to the control sample; 100 g of enriched bread makes it possible to provide the daily demand of a person for protein by 17.6%, in dietary fiber by 6.3% against 13.6% and 1.5%, respectively, in the control sample. The presence of significant amounts of dietary fiber in bread is a positive factor, as these natural sorbents reduce blood cholesterol and the risk of upper digestive and respiratory tract tumors, and regulate microbiocenosis in the gut (Tappy, 2005). Bread enriched with lupine flour has higher protein efficiency and improved amino acid composition (Hanan, 2013).

A new type of bread is characterized by an improved biological value, namely, an increased content of vitamins, pectin substances, and flavonoids. The enrichment of bread contributes to an increase in the content of vitamin E by 9 times, B_1 by 12.5%, which allows us to provide a daily need for them, respectively, by 6.0 and 13.8% due to the consumption of 100 g of bread. An important advantage of bread enriched with lupine flour and cavbuz puree is providing the human body with β–carotene (14%) and flavonoids (6.6%), which are absent in traditional bread. This type of bread is a health product (Birch et al., 2019), which is able to provide the body daily with vitamins of antioxidants and phenolic compounds, which is important for the antioxidant protection of the body (Ebrahimi et al., 2021; Vollmannova et al., 2021). Considering that the minimum preventive rate of pectin consumption in environmentally friendly areas is 2 g per day (Pornsak, 2001), 100 g of developed bread allows to provide 23% of the norm.

Pectin substances are natural sorbents that are able to form gel structures in the intestine, which contributes to the binding of water–soluble toxic compounds, heavy metals and the subsequent removal of their body (Chandel al., 2022; Jandosov et al., 2022), therefore, the sorption ability of enriched bread, which contains natural pectin, to divalent lead ions was determined (Table 10).

Table 10

Sorption capacity of bread enriched with flour of non-alkaloid lupine and cavbuz puree to toxic ions of bivalent lead

Amount by weight of wheat flour,%		Sorption capacity of bread, мг Pb^{2+}/g
Lupine flour	Cavbuz puree	
5	3	2.64±0.14
6	4	2.81±0.11
7	5	3.03±0.08
0	0	0.16±0.12

As the results show, the sorption capacity of bread enriched with non–alkaloid lupine flour and cavbuz puree to toxic divalent lead ions is 25–30 times higher than for control. This is explained by a significant amount of pectin substances – 0.38–0.55 g in 100 g of enriched products. Pectins contain carboxyl groups of galacturonic acid, which gives them sorption–chemical properties to bind metals and form insoluble complexes, this contributes to the elimination of harmful substances from the human body (Wang et al., 2021). In addition, pectins have radioprotective effects (Chandel et al., 2022).

Conclusions

1. Puree cavbuz and lupine flour are the source of a complex of vitamins, protein, and dietary fiber. The use of these vegetable additives to partially replace wheat flour in the recipe of bread will increase the nutritional value of the product.

2. The acidity of the dough and, accordingly, ready-made products with the addition of lupine flour and cavbuz puree, varied within 0.5–1.0 deg. The specific volume of products decreased by 1.1–4.5% compared to control, depending on the addition of enrichment agents, since the high water–binding capacity of dietary fibers of vegetable raw materials weakens the gluten matrix, which affects the volume of bread.
3. Adding to the recipe of wheat bread flour of non–alkaloid varieties of lupine in an amount of 4–7% and cavbuz puree in an amount of 3–5% contributes to an increase in the protein content in the finished product on 20–32%, dietary fibers in 2–3 times, as well as the enrichment of bread with pectin substances, natural enterosorbents, which are absent in the traditional product.
4. The enrichment of wheat bread with plant additives contributes to the improvement of the biological value of the product, in particular, an increase in the content of vitamin E by 9 times, B_1 by 12.5%, which provides a daily human need for them, by 6.0 and 13.8%, respectively, when consumed 100 g of bread. Non-alkaloid lupine flour and cavbuz puree are a source of carotenoids and phenolic compounds that are not present in wheat flour. These ingredients made it possible to enrich the product with β–carotene and flavonoids – their content in a new type of bread is, respectively, 0.71 mg (14% of daily requirement) and 16.4 mg (6.6%) per 100 g of product.
5. Enriched bread has a 25–30 times higher sorption capacity for toxic divalent lead ions than wheat bread.
6. Wheat bread, enriched with flour of non–alkaloid varieties of lupine and cavbuz puree, is a product of a wellness trend.

References

Amoah I., Cairncross C., Elaine Rush E. (2021), Swallowing and liking of vegetable-enriched bread compared with commercial breads as evaluated by older adults, *Nutrition and Food Science Technology*, 7, 599737, DOI: 10.3389/fnut.2020.599737.

Atudorei D., Ropciuc S., Codină G. (2022), Possibilities to use germinated lupine flour as an ingredient in breadmaking to improve the final product quality, *Agronomy*, 12, 667, DOI: 10.3390/agronomy12030667.

Al Omari D.Z., Abdul-Hussain S.S. Ajo R.Y. (2016), Germinated lupin (*Lupinus albus*) flour improves arabic flat bread properties, *Quality Assurance and Safety of Crops & Foods*, 8(1), pp. 57–63, DOI: 10.3920/QAS2014.0441.

Bayramov E., Aliyev S., Gasimova A., Gurbanova S. (2022), Increasing the biological value of bread through the application of pumpkin puree, *Eastern-European Journal of Enterprise Technologies*, pp. 58-68, DOI: 10.15587/1729-4061.2022.254090.

Biehler E., ´Ericmayer F., Hoffmann L., Krause E., Bohn T. (2009), Comparison of 3 spectrophotometric methods for carotenoid determination in frequently consumed fruits and vegetables, *Journal of Food Science*, 75(1), pp. 55–61, DOI: 10.1111/j.1750–3841.2009.01417.x.

Bryant L., Rangan A., Grafenauer S. (2022), Lupins and health outcomes: a literature review, *Nutrients*, 14, pp. 327–339, DOI: 10.3390/nu14020327.

Birch C. S., Bonwick G.A. (2019), Ensuring the future of functional foods, *International Journal of Food Science & Technology*, 54(5), pp. 1467–1485, DOI: 10.1111/ijfs.14060.

Belski R. (2012), Fiber, protein, and lupin–enriched foods: role for improving cardiovascular health, *Advances in Food and Nutrition Research*, 66, pp. 147–215, DOI: 10.1016/B978-0-12-394597-6.00004-5.

Carvajal–Larenas F. E., Linnemann A. R., Nout M. J. R., Koziol M. (2016), Lupinus mutabilis: composition, uses, toxicology, and debittering, *Food Science and Nutrition*,56 (9), pp. 1454–1487, DOI: 10.1080/10408398.2013.772089.

Carlsson N., Borde A., Wölfel S., Åkerman B., Larsson A. (2011), Quantification of protein concentration by the Bradford method in the presence of pharmaceutical polymers, *Analytical Biochemistry*, 411(1), pp. 116–121.

Collin M. S., Venkatraman S. K., Vijayakumar N., Kanimozhi V., Arbaaz S.M. , Sibiya Stacey R.G , Anusha J. , Choudhary R. , Lvov V., Tovar G. I. , Senatov F., Koppala S., Swamiappan S. (2022), Bioaccumulation of lead (Pb) and its effects on human: A review, *Journal of Hazardous Materials Advances*, 7, 100094, DOI: 10.1016/j.hazadv.2022.100094.

Chandel V., Biswas D., Roy S., Vaidya D., Verma A., Gupta A. (2022), Current advancements in pectin: extraction, properties and multifunctional, *Applications Food*, 11(17), 2683, DOI: 10.3390/foods11172683.

Czarnowska-Kujawska M., Starowicz M., Barišic V., Kujawski W. (2022) Health-promoting nutrients and potential bioaccessibility of breads enriched with fresh kale and spinach, *Foods*, 11(21), 3414, DOI: 10.3390/foods11213414.

Dong R., Yu B., Yan S. , Qiu Z., Lei J., Chen C., Li Y., Cao B. (2020), Analysis of vitamin P content and inheritance models in eggplant, *Horticultural Plant Journal, 6(4),* pp. 240-246

Drobot V.I. (2019), *Dovidnyk z Tekhnolohii Khlibopekarskoho Vyrobnytstva*, ProfKnyha, Kyiv.

Erickson M. (2005), *Deep Frying. Chemistry, Nutrition, and Practical Applications*, Urbana, Illinois.

Ebrahimi M., Sadeghi A., Sarani A, Purabdolah H. (2021), Enhancement of technological functionality of white wheat bread using wheat germ sourdough along with dehydrated spinach puree, *Journal of Agricultural Science and Technology*, 23(4), pp. 839–851.

Gamna F., Spriano S. (2021), Vitamin E: a review of its application and methods of detection when combined with implant biomaterials, *Materials (Basel)*, 14(13), 3691.

Guiné R., Correia P., Gonzaga M., Batista L., Beirão-da-Costa M. (2015). Development and characterization of wheat bread with lupin flour, *Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*, 9, pp. 923–927.

Guo J., Knol L., Yang X., Kong L. (2022) Dietary fiber intake is inversely related to serum heavy metal concentrations among US adults consuming recommended amounts of seafood: NHANES 2013–2014, *Food Frontier*, 3(1), pp. 142–149. DOI: 10.1002/fft2.114

Hanan A.F. (2013), Effect of fortification pan bread with lupine flour on the chemical, rheological and nutritional properties, *Journal Food and Dairy Science*, 4(3), pp. 65–75.

Hertzler S. R., Lieblein–Boff J. C., Weiler M., Allgeier C. (2020), Plant proteins: assessing their nutritional quality and effects on health and physical function, *Nutrients,* 12(12), 3704, DOI: 10.3390/nu12123704.

Herrera-Ardila Y.M., Orrego D., Bejarano-López A.F., Klotz-Ceberio B. (2022), Effect of heat treatment on vitamin content during the manufacture of food products at industrial scale, *Dyna,* 89, 223, DOI: 10.15446/dyna.v89n223.99775.

Ioniță-Mîndrican C.-B., Ziani K., Mititelu M, Oprea E., Neacșu S. M. , Moroșan E., Dumitrescu D.-E., Roșca A.C., Drăgănescu D., Negrei C. (2022), Therapeutic benefits and dietary restrictions of fiber intake: a state of the art review, *Nutrients,* 14(13), 2641, DOI: 10.3390/nu14132641.

Jandosov J., Alavijeh M., Sultakhan S., Baimenov A., Bernardo M., Sakipova Z., Azat S., Lyubchyk S., Zhylybayeva N., Naurzbayeva G., Mansurov Z., Mikhalovsky S., Berillo D. (2022), Activated carbon/pectin composite enterosorbent for human protection from intoxication with xenobiotics Pb(II) and sodium diclofenac, *Molecules,* 27, 2296, DOI: 10.3390/molecules27072296.

Krawęcka A., Sobota A., Zarzycki P. (2022), The effect of the addition of low-alkaloid lupine flour on the glycemic index in vivo and the physicochemical properties and cooking quality of durum wheat pasta, *Foods,* 11(20), 3216, DOI: 10.3390/foods11203216.

Lazdauskienė J., Kepalienė I., Liepienė N., Vaičiulytė-Funk L. (2022), The influence of lupine seeds flour addition on wheat-rye bread quality, *Žemės Ūkio Mokslai,* 29(1), pp. 28–35.

Lang L., Chiu K., Lang Q. (2008), Spectrophotometric determination of lead, *Pharmaceutical Technology,* 32 (4), 3412.

Mazur V. A., Pantsyreva H. V., Didur I. M., Prokopchuk V. M. (2018), *Liupyn Bilyi: Henetychnyi Potentsial ta Yoho Realizatsiia u Silskohospodarske Vyrobnytstvo,* Tvory,Vinnytsia.

Maghaydah S., Alkahlout A., Abughoush M., Nazieh I. Al Khalaileh, Amin N. Olaimat, Murad A. Al-Holy, Ajo R., Choudhury I., Hayajneh W. (2022), Novel gluten–free rolls by substituting wheat flour with resistant starch, lupine and flaxseed flour, *Foods,* 11, 1022, DOI: 10.3390/foods11071022.

Majidi M., Y–ALQubury H. (2016), Determination of Vitamin C(ascorbic acid) Contents in various fruit and vegetable by UV–spectrophotometry and titration methods, *Journal of Chemical and Pharmaceutical Sciences,* 9 (4), pp. 2972–2974.

Malavi D., Mbogo D., Moyo M., Mwaura L., Low J., Muzhingi T. (2022). Effect of orange-fleshed sweet potato purée and wheat flour blends on β-carotene, selected physicochemical and microbiological properties of bread, *Foods,* 11(7), 1051, DOI: 10.3390/foods11071051.

Möller J. (2008) Animal feeding stuff – global standard for the determination of acid detergent fibre (ADF) and lignin, *In Focus,* 32(2), pp. 22–24.

Phillips M. M., (2012), Analytical approaches to determination of total choline in foods and dietary supplements, *Analytical Bioanalytical* Chem*ical,* 403, pp. 2103–2112, DOI: 10.1007/s00216–011–5652–5.

Pollard N. J., Stoddard F. L., Popineau Y., Wrigley C.W.(2002), Lupin flours as additives: dough mixing, breadmaking, emulsifying, and foaming, *Cereal Chemistry* 79, pp. 662–669, DOI:10.1094/CCHEM.2002.79.5.662.

Prusinski J. (2017), White lupin (*Lupinus albus L.*) – nutritional and health values in human nutrition – a review, *Czech Journal of Food Science,* 35, (2), pp.95–105, DOI.org/10.1155/2021/5512236.

Potopalskyi A.I. Drozda V.F., Katsan V.A. (2019), *Kavbuz Zdoroviaha — skarbnytsia zdorovia, krasy i dovholittia,* Prostir, Kyiv.

Pornsak S. (2001), Pectin: The role in health, *Journal of Silpakorn University,* 21, pp. 60–77.

Ratoshniuk V.I., Havryliuk M.M. (2020), Liupyn vuzkolystyi – kultura universalnoho vykorystannia u zoni Polissia Ukrainy, *Visnyk Ahrarnoi Nauky*, 8(809), pp. 26–37.

Ruiz-López M. A., Barrientos-Ramírez L., García-López P. M., Valdés-MiramontesE. H., Zamora-Natera J.F., Rodríguez-Macias R., Salcedo-Pérez E. (2019), Nutritional and bioactive compounds in mexican lupin beans species: a mini–review, *Nutrients*, 11(8), pp.1785–1796, DOI: 10.3390/nu11081785.

Saccotelli M.A., Spinelli S., Conte A., Del Nobile M. A. (2018), Gluten-Free bread enriched with vegetable flours, *Food and Nutrition Sciences,* 9(4), 30384, DOI: 10.4236/fns.2018.94028.

Subroto E., Jeanette G., Meiyanasari Y., Luwinsky I., Baraddiaz S. (2020), Review on the analysis methods of starch, amylose, amylopectin in food and agricultural products, *International Journal of Emerging Trends in Engineering Research,* 8 (7), pp. 3519–3524, DOI: 10.30534/ijeter/2020/103872020.

Tan C., Wei H., Zhao X., Xu C., Peng J. (2017), Effects of dietary fibers with high water-binding capacity and swelling capacity on gastrointestinal functions, food intake and body weight in male rats, *Food & Nutrition Research*, 61(1), 1308118, DOI: 10.1080/16546628.2017.1308118.

Tyl C., Sadler G. D. (2017), pH and titratable acidity, In: Nielsen S.S. (eds.), *Food Analysis*, Food Science Text Series, Springer, Cham, pp. 389–406, DOI: 10.1007/978-3-319-45776-5 22.

Tappy L. (2006), Effects of break fast cereals containing various amounts of beta–glucan fibres on plasma glucose and insulin responses in NIDDM subjects, *Diabetes Care,* 19, pp. 831–834.

Vollmannova A., Lidikova J., Musilova J., Snirc M., Bojnanska T., Urminska D., Tirdilova I., Zetochova E. (2021), White lupin as a promising source of antioxidant phenolics for functional food production, *Journal of Food Quality,* 202, pp. 102–113, DOI:10.1155/2021/5512236

Villarino C. B. J., Jayasena V., Coorey R., Chakrabarti–Bell S., Johnson S. K. (2016), Nutritional, health and technological functionality of lupin flour addition to bread and other baked products: benefits and challenges, critical reviews in food, *Science and Nutrition*, 56(5), pp. 835–857, DOI: 10.1080/10408398.2013.814044.

Waterhouse A. L. (2002), Determination of total phenolics, *Current Protocols in Food Analytical Chemistry*, 6(1), pp. I1.1.1–I1.1.8, DOI: 10.1002/0471142913.fai0101s06.

Wang R., Li Y., Shuai X., Liang R., Chen J., Liu C. (2021), Pectin/Activated carbon–based porous microsphere for Pb^{2+} adsorption: Characterization and adsorption behaviour, *Polymers,* 13(15), 2453, DOI: 10.3390/polym13152453.

Zajicek J.L., Tillitt D.E., Brown S.B., Brown L.R., Honeyfield D.C., Fitzsimons J.D. (2005), A rapid solid–phase extraction fluorometric method for thiamine and riboflavin in salmonid eggs, *Journal of Aquatic Animal Health*, 17, pp. 95–105, DOI: 10.1577/H03–079.1.

Effects of different phosphate content on the quality of wheat bran chicken sausage

Olena Stabnikova[1], Svitlana Danylenko[2] , Tetyana Kryzhska[3], Feifei Shang[3,4], Zhenhua Duan[4]

1 – National University of Food Technologies, Ukraine
2 – Institute of Food Resources of NAAS, Department of Biotechnology, Ukraine
3 – Sumy National Agrarian University, Sum, Ukraine
4 – School of Food and Bioengineering, Hezhou University, Hezhou, China

Keywords:

Chicken
Sausages
Phosphate
Wheat Bran
Quality
Properties

Article history:

Received 15.03.2022
Received in revised form 30.11.2022
Accepted 30.12.2022

Corresponding author:

Olena Stabnikova
E-mail: stabstab6@gmail.com

DOI: 10.24263/2304-974X-2022-11-4-8

Abstract

Introduction. The addition of phosphates improves the emulsifying and gelling properties of meat proteins as well as overall product quality. The effect of phosphate addition on the properties of low-fat chicken sausages containing wheat bran was studied in this article.

Materials and methods. Cooking loss, emulsification stability, water distribution, texture and sensory characteristics of wheat bran chicken sausage added with different amounts of complex phosphate were determined.

Results and discussion. The positive influence of phosphate addition on technological and textual properties of meat products is known, however taking into account consumer's acceptability, determination of phosphate content in sausages ensuring their high quality but not but not exceeding this value is needed. Low–fat chicken sausages with increased dietary fiber content due to inclusion in the sausage formulation of wheat bran were used as the object of the study. Comparative characteristics of wheat bran chicken sausage added with different amounts of complex phosphate, namely, 1.0, 1.5 or 2.0 g to 400 g of ground chicken meat were determined. It was shown that the minimum cooking water and fat losses were observed when addition of 1.5 g of complex phosphate was used. Thus, addition of 1.5 g of complex phosphate to 400 g of ground chicken meat ensured better retaining of water and fat, lowest cooking loss and highest emulsifying stability than in cases when 1.0 or 2.0 g of complex phosphate were added. At the same time, the results showed that the sausage containing 1.5 g phosphate per 400 g of ground chicken had the highest hardness, elasticity and chewiness, and the highest overall acceptability score of sensory evaluation, but the difference was not significant ($P>0.05$). Addition of 1.5 g phosphate per 400 g of ground chicken reduced the fluidity of free water in the sausage, and thus enhanced the water-retaining ability of chicken sausage. In addition, the results of the pseudo-color map showed that the semi-bound water of the S2 and S3 treatment groups increased significantly.

Conclusions. Addition of complex phosphate, 0.2 %, in formulation of low-fat wheat bran chicken sausages decreases cooking, moisture and fat losses, and improves the texture and sensory properties of the final product.

Introduction

The world produces a huge variety of different types of sausages, such as ham, smoked, Chinese, fermented, mixed and others, in the preparation of which various types of meat are used (Marcos et al., 2016; Wang et al., 2021; Wang et al., 2022). Due to its high protein content and balanced nutritional composition, the use of chicken meat as a raw material for the production of sausages is extremely popular (Delgado-Pando et al., 2010; Shan et al., 2017).

Traditional sausages are prepared using a mixture of grounded meat, animal fat, salt, water, spices, and other additives and have high enough fat content up to 30% allowing to produce emulsion needed for gelling of meat product. Despite those meat products having high popularity among consumers, the high fat content containing mainly saturated fatty acids is an issue of significant health concerns (Stabnikova et al., 2021). Thus, a lot of studies to reduce the animal fat content in the meat product by partial replacement with different fat substitutes are conducting at recent time (Antonini et al., 2020; Choi et al., 2012; Pintado et al., 2016).

Another way to reduce animal fat content in the meat products is its partial replacement with different plant materials such as grape seed oil (Kim et al., 2020), pineapple dietary fibres (Henning et al., 2016), dietary fiber extracted from makgeolli lees (Choi et al., 2014), chia seeds (Ding et al., 2017), oatmeal (Yang et al., 2010) and many others. Partial replacement of fat, 10 %, with hydrated oatmeal resulted in improvement of technological parameters and sensory properties of low-fat sausages (Kim et al., 2020), pineapple dietary fibres（Henning et al., 2016), dietary fiber extracted from makgeolli lees（Choi et al., 2014), chia seeds (Ding et al., 2017), and oatmeal (Yang et al., 2010). Partial replacement of fat, 10 %, with hydrated oatmeal resulted in improvement of technological parameters and sensory properties of low-fat sausages (Yang et al., 2010). Addition of wheat bran together with dried carrot pomace to chicken sausage in quantity 6% each was recommended to increase dietary fiber content under keeping good level of acceptability (Yadav et al., 2018).

Application of emulsion gels as animal fat replacement is one of the main trends for manufacturing products with high sensory quality while reducing its fat content (Ren et al., 2022). Application of fat emulsions prevents moisture loss during heat treatment and results in the manufacturing of meat products with high structural and mechanical properties. There are a lot of different emulsifying agents. There is known addition of polysaccharide-based emulsion gels for partial replacement (20 and 40%) of pork back-fat in production of dried fermented sausages (Chen et al., 2021). Altogether with improvement of nutritional value there are a lot of studies aimed to enhance the acceptability of low fat sausages. Thus, addition of powder of *Lamina japonica*, 1%, to the breakfast sausage allows to maintain their high overall sensory quality (Kim et al., 2010). Addition of gelatin hydrolysates significantly improved the process performance of cooked sausage (Ham et al., 2020). The addition of 1.0% curdlan improved the functional and textural properties of low-fat sausages (Lee and Chin, 2019).

Phosphates are very different from other emulsifiers traditionally added to meat products. The use of phosphorus-containing food additives in the processing of poultry and red meat products, including the direct addition of phosphates during the preparation of sausages, was allowed by a 1982 ruling of the Food Safety and Inspection Service of the United States Department of Agriculture (Sherman and Mehta, 2009). The addition of phosphates improves the emulsifying and gelling properties of meat proteins as well as overall meat product quality. Addition of phosphates stabilizes the pH value, increases water-holding capacity, reduces moisture loss during cooking, improves texture and sensory properties (tenderness, juiciness, color and taste), and extends shelf life of the finished product (Wang et al., 2009).

The aim of the present study was to evaluate the effect of phosphate addition on the quality of low-fat chicken sausage containing wheat bran to make recommendations for their production.

Materials and Methods

Materials

Chicken breast, fatty pork, wheat bran, tapioca starch, modified tapioca starch, potato starch, ice water, salt, five-spice powder, pepper, rice wine, red yeast rice powder, beet red, casings (commercially salt-cured fresh pig small intestine) were used as raw materials for low-fat sausage preparation. Wheat bran (Henan Jinyuan Grain & Oil Company, Zhengzhou, China, 18% protein, 0.6% fat, and 31.4% dietary fiber) (Shang et al., 2022) was crushed and sifted (part below 80 mesh). Complex phosphate (Harsen Foods (Hongkong) Co., LTD, Shantou, China including sodium pyrophosphate, 60%; sodium tripolyphosphate, 39%, and sodium hexametaphosphate, 1%) was used to study effect of phosphate addition on sausage quality. All these phosphate components are allowed to be used as phosphate additives in the sausage preparation (Knipe, 1983).

Instruments and equipment

Colorimeter (color difference meter CR-400, Shoufeng Instrument Technology Co., Ltd, Changzhou, China) was used to check colour difference of meat products; texture profile analysis was done at a room temperature with a texture analyzer (TA.XT PLUS, Stable Micro System, UK). Water distribution analyses were performed with a low field nuclear magnetic resonance instrument, nuclear magnetic resonance imaging analyzer (NMI20, Shanghai Newmai Electronic Technology Co., Ltd, Shanghai, China).

Processing of wheat bran chicken sausage

Stuffing for sausages was prepared by the following steps. Defrosting chicken breast was cleaned, cut and grounded. Pig skin was soaked in water added with a small amount of rice wine for 30 min. Grounded chicken breasts were added with other ingredients according to the recipes, mixed together, stirred evenly, and put into the sausage casing. The base formulation of the chicken sausages included the following ingredients, g: chicken breast, 400; pig skin, 80; pork fat, 50; wheat bran (part below 80 mesh), 6; cassava starch, 35; cassava denaturant starch, 20; potato starch, 20; ice water, 100; salt, 7; spices, 4.5; pepper, 0.5; rice wine, 25; red rice powder, 1.5, and beet red 2.0. To study the phosphate influence on the quality of low-fat chicken sausage containing wheat bran three samples were prepared with addition of complex phosphate, g: 1.0 (S1), 1.5 (S2), and 2.0 (S3). The sausage ingredients were chopped and put into the pig's small intestine. The chicken sausages were placed in a water bath at a temperature of 80 °C for 30 min, cooled to room temperature (about 20 °C) and stored in the refrigerator.

Determination of cooking, moisture, and fat losses

To determine the cook loss, 35 g of sausage raw materials were chopped, placed in a 50 ml centrifuge tube, and centrifuged (3000 rpm, 5 min) to remove air bubbles. Then it was heated in a water bath (75 °C, 30 min), cooled at room temperature for 1 h, and weight after cooling was recorded (Choi et al., 2015). The cooking loss was calculated by formula (1):

$$\text{Cooking loss, \%} = (W_0 - W_1)/W_0 \times 100, \quad (1)$$

where W_0 denotes the weight of raw meat sample before cooking, g; W_1 denotes the weight of cooked meat sample, g.

To calculate moisture loss and fat loss the liquid lost during heating was poured into a glass dish and dried at 105 °C for 16 h. The weight lost by evaporation was water loss and the remaining mass on the plate after drying was fat loss. The calculation formulas for water loss and fat loss were (2) and (3):

$$\text{Moisture loss, \%} = (W_2 - W_3)/W_0 \times 100, \quad (2)$$

$$\text{Fat loss, \%} = W_3/W_0 \times 100, \quad (3)$$

where W_0 denotes the weight of raw meat sample before cooking, g; W_1 denotes the weight of cooked meat samples, g; W_2 denotes the weight of cooking liquid, g; W_3 denotes the remaining weight of cooking liquid after drying.

Determination of color difference

The chicken sausages stored at 4°C were kept before measurement at room temperature for 1 h. O/D test was used to determine the brightness value, redness value, and yellowness value.

Determination of pH

5 g of crushed sausage samples were placed into a 50 mL beaker and 20 mL of distilled water were added. Magnetically stirring was provided for 5 min, and the mixture was allowed to stand at room temperature for 30 min. pH of the upper liquid was measured with a pH meter.

Determination of moisture content

Standard drying method (AOAC, 2006) was used to determine moisture content in meat sample dried at 100-102 °C to a constant weight.

Performance of texture planer analysis

The chicken sausages stored at 4 °C were kept before measurement at room temperature for 1 hour, the samples were cut into cylinders of 40×20 mm (height × diameter), and the texture was determined using texture planer analysis (TPA). The probe model was P/5. Set the measured parameters, 5 mm/s before the test rate, 1 mm/s test rate, 1 mm/s after the test rate, 50%, and the compression ratio, 5 g trigger force, was used. The measurement indicators include six parameters such as hardness, elasticity, cohesiveness, chewiness, adhesiveness, and recovery.

Determination of moisture distribution

To determine the dynamic distribution of moisture inside sausages low-field nuclear magnetic resonance (LF-NMR) technology was used (Aursand et al., 2008; Chen et al., 2019).

The sausage was cut into pieces with size of 1 cm × 1 cm × 4 cm and placed in a nuclear magnetic test tube (the diameter of the test tube was 1.8 cm, the height was 18 cm). The Carr-PurcellMeiboom-Gill (CPMG) program was used to determine the sample relaxation time (T2). Lateral relaxation (T2) and corresponding relaxation time (T2B, T21 and T22) and amplitude (A2B, A21 and A22) were determined using the CONTIN imaging software that comes with the system to scan the sample into a magnetic resonance imaging (MRI) image using the IPT.2014 pseudocolor software to process the MRI pseudocolor image (Luo et al., 2020).

Sensory evaluation

10 food specialists with sensory evaluation experience were invited to form the evaluation team. The color, hardness, flavor, viscosity and overall acceptability of bran chicken sausage were evaluated according to the Sensory evaluation standard (Chen et al., 2019; Shang et al., 2019) (Table 1).

Table 1

Sensory evaluation standard

Evaluation index	**Evaluation points**		
	1~3 points	**4~6 points**	**7~9 points**
Color	No appetite, poor color	Average appetite, normal color,	Appetite, attractive color
Texture	The taste is rough and hard	The taste is slightly rough and hard	The taste is fine and elastic
Flavor	No sausage taste	Average sausage taste	Suitable sausage taste
Viscosity	Sticky teeth	Slightly sticky teeth	Non-sticky teeth
Overall acceptability	Not accept	Accept	Like

Statistical analysis

All measurements were performed at least in triplicates, and the data are expressed as mean ± standard deviation ($\overline{X} \pm S$). All data used the one-way analysis of variance (ANOVA) post-multiple comparison method in the IBM SPSS Statistics 22 data editor, set the significance level to P=0.05, and used the LSD program to analyze the significant differences (P<0.05 is significant). Use Microsoft Excel 2017 software to draw charts.

Results and discussion

Low–fat chicken sausages with increased dietary fiber content due to including in the sausage formulation of wheat bran were used as an object of study (Shang, 2019). To evaluate incorporation of complex phosphate to chicken- sausage on their technological and sensory properties, three samples of sausages with the complex phosphate added in quantity of 1.0 g (S1), 1.5 g (S2), and 2.0 g (S3) to 400 g of ground chicken meat were prepared and studied.

Effects of different phosphate content on cooking loss and emulsification stability of ground chicken meat

Results of the study of the effects of different phosphate amounts on cooking loss and emulsification stability, which was indirectly evaluated by water loss and fat loss, of ground chicken meat are shown in Table 2.

Table 2

Effects of different phosphate content on cooking loss and emulsification stability of ground chicken meat

Samples with phosphate content	Cooking loss, %	Moisture loss, %	Fat loss,%
1.0 g/400 g of ground chicken meat (S1)	9.26±0.29[a]	9.07±0.30[a]	0.19±0.05[a]
1.5 g/400 g of ground chicken meat (S2)	7.18±0.20[c]	7.10±0.18[c]	0.08±0.03[b]
2.0 g/400 g of ground chicken meat (S3)	8.24±0.22[b]	8.14±0.25[b]	0.10±0.03[b]

Note: Means within a column with different letters are significantly different ($p<0.05$).

The stabilizing and emulsifying action of phosphate used in manufacturing of emulsified meat products is well known (Xu et al., 2021). The decrease of the phosphate content led to lowering of the cooking yield, emulsion stability and texture properties of meat products (Pinton et al., 2019), meanwhile, the high amounts of phosphate is not welcomed by consumers（Goemaere et al., 2021). So, it is necessary to determine the optimum content of phosphate in the meat product ensured its high quality but not to exceed this value. In our research it was shown that the minimum cooking loss, water loss and fat loss was observed for sample 2 (S2) of low-fat chicken sausages, followed by sample 3 (S3), meanwhile the highest losses were found for sample 1 (S1). Thus, addition of 1.5 g of complex phosphate to 400 g of ground chicken meat ensured better retaining of water and fat, lowest cooking loss and highest emulsifying stability than in cases when 1 or 2 g of complex phosphate were used.

Effects of different phosphate content on chicken sausage color

Color is an important characteristic of sausages. The effect of different phosphate content in low-fat chicken sausages is shown in Table 3.

According to the results, the brightness values of the sausages S2 and S3 were higher than that of the ground meat, meanwhile the redness values of sausages S2 and S3 decreased compared with the ground meat. The yellowness value of sausage S2 increased, indicating that the red color of processed sausages was less and more yellow. Increasing sodium tripolyphosphate and salt contents did not affect lightness ($p > 0.05$), but did increase redness and yellowness ($p < 0.05$) of low-fat chicken sausages (Choi et al., 2020).

Table 3

Effects of different phosphate content on the color of ground chicken meat and chicken sausages

Sample	Brightness value		Redness value		Yellowness value	
	Ground meat	Sausage	Ground meat	Sausage	Ground meat	Sausage
S1	64.83 ±0.29[a]	62.86 ±0.69[b]	21.34 ±0.20[c]	20.23 ±0.47[a]	10.48 ±0.49[b]	12.51 ±0.10[a]
S2	61.24 ±1.28[c]	61.64 ±0.81[b]	24.11 ±0.36[a]	17.89 ±0.22[b]	11.92 ±0.22[a]	12.04 ±0.34[a]
S3	62.98 ±0.22[b]	69.14 ±0.44[a]	22.88 ±0.66[b]	17.15 ±1.71[b]	11.10 ±0.47[ab]	10.99 ±0.24[b]

Note: Means within a column with different letters are significantly different ($p<0.05$).

Effects of different phosphate content on moisture content and pH value

According to the results present in Table 4, the moisture content of ground chicken meat increased with the increase of the amount of phosphate, and there was a significant difference among the studied samples.

Table 4

Effects of different phosphate content on moisture and pH of ground chicken meat and chicken sausage

Sample	Moisture, %		pH, units	
	Ground meat	Sausage	Ground meat	Sausage
S1	48.73±0.59[c]	59.85±0.45[b]	6.29±0.01[ab]	6.33±0.03[b]
S2	54.70±0.38[b]	63.43±0.44[a]	6.22±0.05[b]	6.31±0.04[b]
S3	59.21±0.29[a]	63.44±0.87[a]	6.33±0.05[a]	6.48±0.03[a]

Note: Means within a column with different letters are significantly different ($p<0.05$).

The moisture contents in S2 and S3 sausages were significantly higher than in S1, but there was no difference in the moisture content in sausages S2 and S3. There was no significant difference in pH between samples S1 and S2, but values of pH of the ground meat and sausages of sample S3 were a little bit higher than those for S1 and S2.

Effects of different phosphate content on texture properties of sausages

The texture is one of the most important sensory characteristics of emulsified sausages. Texture properties of low-fat chicken sausages with different amounts of complex phosphate were estimated (Table 5).

It was shown that addition of phosphates in emulsion-type sausage could change their texture characteristics and the amount of phosphate added positively correlated with the hardness of the sausages made from frozen meat (Wang et al., 2009). According to our results, the hardness of low-fat chicken sausages with the addition of 1.5 g of complex phosphate per 400 g of ground chicken meat (sample S2) was significantly higher than that of the sausage prepared with 1.0 g of complex phosphate per 400 g of ground chicken meat (sample S1) ($p<0.05$). Meanwhile, all other texture parameters did not differ significantly for all tested sausages (Table 5). However, springiness and chewiness were better in sample S2 ($p<0.05$).

On the whole, the sample S2 with the content of complex phosphate around 0.2% had the best quality and taste. In another study, the best textual properties of low-fat chicken sausage were observed when sodium tripolyphosphate, 0.3%, was added (p < 0.05) (Choi et al., 2009).

Table 5

Effect of different phosphate content on texture of chicken sausage

Sample	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
S1	91.90 ±10.88[b]	0.39 ±0.17[a]	0.39 ±0.22[a]	36.54 ±20.70[a]	16.44 ±13.36[a]	0.05 ±0.01[a]
S2	156.44 ±22.52[a]	0.58 ±0.05[a]	0.27 ±0.04[a]	34.25 ±4.17[a]	25.15 ±2.76[a]	0.05 ±0.01[a]
S3	113.83 ±28.31[ab]	0.17 ±0.04[a]	0.17 ±0.05[a]	18.41 ±3.72[a]	13.13 ±1.18[a]	0.03 ±0.00[a]

Note: Means within a column with different letters are significantly different (p<0.05).

It was shown that addition of phosphates in emulsion-type sausage could change their texture characteristics and the amount of phosphate added positively correlated with the hardness of the sausages made from frozen meat (Wang et al., 2009). According to our results, the hardness of low-fat chicken sausages with the addition of 1.5 g of complex phosphate per 400 g of ground chicken meat (sample S2) was significantly higher than that of the sausage prepared with 1.0 g of complex phosphate per 400 g of ground chicken meat (sample S1) (p<0.05). Meanwhile, all other texture parameters did not differ significantly for all tested sausages (Table 5). However, springiness and chewiness were better in sample S2 (p<0.05). On the whole, the sample S2 with the content of complex phosphate around 0.2% had the best quality and taste. In another study, the best textual properties of low-fat chicken sausage were observed when sodium tripolyphosphate, 0.3%, was added (p < 0.05) (Choi et al., 2009).

Effects of different phosphate content on distribution of water in chicken sausages

Low-field nuclear magnetic resonance technology was used to study the distribution of water in sausages. Effects of different phosphate content on distribution of water in chicken sausages is represented in Figure 1.

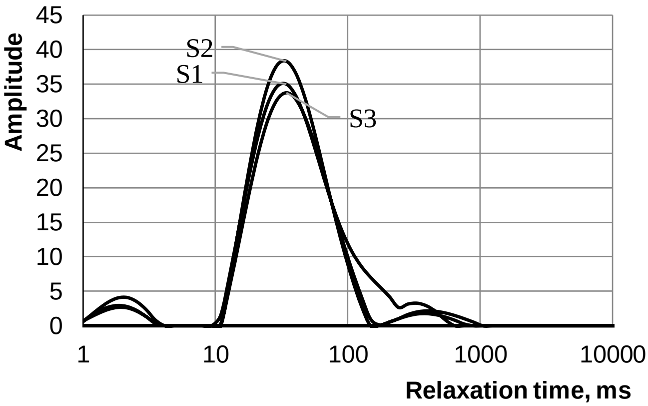


Figure 1. Effects of different phosphate content on distribution of moisture in chicken sausage

The amount of free water is in the range of 0-10 milliseconds (ms) and moves towards a short relaxation time. The bound water (namely, by phosphates and protein complex) and immobilized water don't move and are in the range from 100-1000 ms. This is the interval for water strongly bound to the meat proteins. The interval of 10 to100 ms represents weakly bound water. The highest peak in this interval was observed for sample S2. Analysis of curves presented in Fig. 2 indicates that the increase of the phosphate amount in sausage S2 increases the amplitude of weakly bound water and contributes to better binding of free water improving the water-holding capacity of chicken sausages and obtaining a dense texture of the meat product. This is in a study by Shao et al. (2016) also noted that the addition of phosphate to ground pork meat shortens the water relaxation time, and the addition of phosphate and NaCl to sausage increases their water-holding capacity.

Nuclear magnetic imaging analysis

Distribution of water in low-fat wheat bran chicken sausages prepared with different content of phosphate was studied by low-field nuclear magnetic resonance (Figure 2).

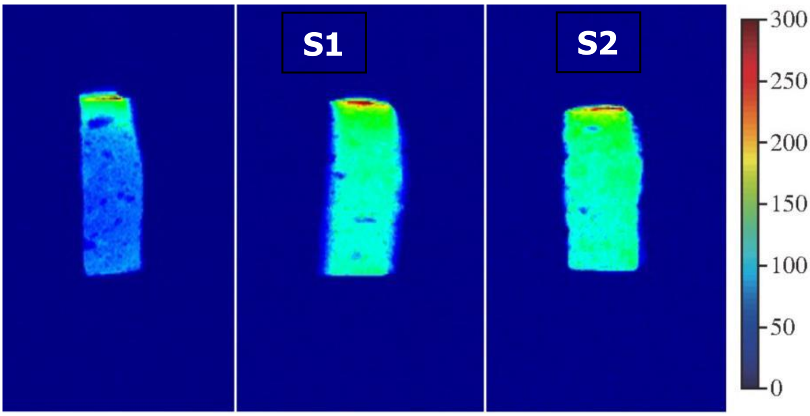


Figure 2. Pseudo-color map of chicken sausage with different phosphate content per 400 g of ground chicken meat:
1.0 g (S1); 1.5 g (S2), and 2.0 g (S3).

Green color corresponds to strongly bound water molecules in sausages, and blue color reflects the amount of free water. According to the nuclear magnetic imagines, increase of phosphate amounts resulted in an increase of water bound molecules content in sausages S2 and S3 that indicates a better binding of water by phosphates and a network of proteins that ensures improving of the water holding capacity of low-fat chicken sausages.

Effects of different phosphate content on sensory evaluation of wheat bran chicken sausages

Sensory properties of low-fat wheat bran sausages added with different amounts of phosphate were evaluated to assess the consumer's acceptance of the product (Table 6).

Table 6

Effect of different phosphate content on sensory evaluation of wheat bran chicken sausages

Sausages	Color	Texture	Flavor	Viscosity	Acceptability
S1	3.80±0.79[a]	4.10±0.99[a]	4.10±1.85[a]	4.00±1.76[a]	5.30±1.06[a]
S2	4.30±1.42[a]	4.50±1.08[a]	5.10±1.29[a]	5.00±1.56[a]	5.40±1.43[a]
S3	4.50±1.08[a]	4.00±1.05[a]	4.80±1.55[a]	3.90±1.52[a]	5.30±1.20[a]

It was found that phosphate addition in studied amounts had no significant effect on the sensory scores of wheat bran chicken sausage ($P< 0.05$). The sausages S2 with addition of 0.2% of phosphate (1.5 g per 400 g of ground chicken meat) received the highest scores by the sensory evaluation team members in terms of color, texture, flavor, viscosity, and overall acceptability. This evaluation result was consistent with the physicochemical property analysis.

Conclusion

Addition of 1.5 g of complex phosphate in formulation of low-fat chicken sausages (400 g chicken breast, 50 g pork back fat, 80 g pig skin and 6 g wheat bran as raw materials) decreases cooking loss,moisture loss andfat loss; improved the texture properties, mainly the hardness ($P>0.05$), meanwhile other characteristics varied but were not significantly different, and increases water holding capacity and sensory evaluation value of the sausages. So, it can be recommended to add 0.2% of complex phosphate in formulation of low-fat wheat bran chicken sausages to enhance their technological and sensory properties.

Acknowledgements. The experiment was supported by the Top discipline of food science and engineering in Guangxi Province.

Reference

Antonini E., Torri L., Piochi M., Cabrino G., Assunta M. (2020), Nutritional, antioxidant and sensory properties of functional beef burgers formulated with chia seeds and goji puree, before and after in vitro digestion, *Meat Science*, 161, Article 108021, DOI: 10.1016/j.meatsci.2019.108021.

AOAC (2006), AOAC Official Method 950.46, Moisture in meat, Available from www.aoac.org/omarev1/950_46.pdf.

Aursand I. G., Gallart-Jornet L., Erikson U., Axelsonet D. E., Rustad T. (2008), Water distribution in brine salted cod (*Gadus morhua*) and salmon (*Salmo salar*): a low-field LF-NMR study, *Journal of Agricultural and Food Chemistry*, 56(15), pp. 6252-6260, DOI: 10.1021/jf800369n.

Chen Y., Jiang S., Cao C., Chen J., Kong B., Liu Q. (2019), Evaluation of the quality of frankfurters prepared with highly stable vegetable oil-in-water pre-emulsion as a partial replacer of pork back fat, *Food Science*, 40(24), pp. 86-93, DOI:

10.7506/spkx1002-6630-20180906-060.

Chen J. X., Zhao J. H., Li X., Liu Q., Kong B. H. (2021), Composite gel fabricated with konjac glucomannan and carrageenan could be used as a cube fat substitute to partially replace pork fat in Harbin dry sausages, *Foods*, 10(7), pp. 1460, DOI: 10.3390/foods10071460.

Choi J. S., Chin K. B. (2009), Evaluation of physicochemical and textural properties of chicken breast sausages containing various combinations of salt and sodium tripolyphosphate, *Journal of Animal Science and Technology*, 62(4), pp. 577-586, DOI: 10.5187/jast.2020.62.4.577.

Choi J. H., Han D. J., Kim H. Y., Kim H. W., Lee M. A., Chung H. J., Kim C. J. (2012), Effects of *Laminaria japonica* on the physico-chemical and sensory characteristics of reduced-fat pork patties, *Meat Science*, 91(1), pp. 1–7, DOI: 10.1016/j.meatsci.2011.11.011.

Choi Y. S., Kim H. W., Hwang K. E., Song D. H., Choi J. H., Lee M. A., Chung H. J., Kim C. J. (2014), Physicochemical properties and sensory characteristics of reduced-fat frankfurters with pork back fat replaced by dietary fiber extracted from makgeolli lees, *Meat Science*, 96(2), Part A, pp. 892–900, DOI: 10.1016/j.meatsci.2013.08.033.

Choi Y. S., Kim H. W., Hwang K. E., Song D. H., Jeong T. J., Kim Y. B., Jeon K. H., Kim C. J. (2015), Effects of fat levels and rice bran fiber on the chemical, textural, and sensory properties of frankfurters, *Food Science and Biotechnology*, 24(2), pp. 489–495, DOI: 10.1007/s10068-015-0064-5.

Ding Y., Lin H. W., Lin Y., Yang D., Yu Y., Chen J., Wang S., Chen Y. (2017), Nutritional composition in the chia seed and its processing properties on restructured ham-like products, *Journal of Food and Drug Analysis*, 26, 124–134, DOI: 10.1016/j.jfda.2016.12.012.

Goemaere O., Glorieux S., Govaert M., Steen L., Fraeye I. (2021), Phosphate elimination in emulsified meat products: Impact of protein-based ingredients on quality characteristics, *Foods*, 10(4), pp. 882. DOI: 10.3390/foods10040882.

Kim H. W., Hwang K. E., Song D. H., Choi J. H., Lee M. A., Chung H. J., Kim C. J. (2014), Physicochemical properties and sensory characteristics of reduced-fat frankfurters with pork back fat replaced by dietary fiber extracted from makgeolli lees, *Meat Science*, 96(2), Part A, pp. 892–900, DOI: 10.1016/j.meatsci.2013.08.033.

Delgado-Pando G., Cofrades S., Ruiz-Capillas C., Jiménez-Colmenero F. (2010), Healthier lipid combination as functional ingredient influencing sensory and technological properties of low-fat frankfurters, *European Journal of Lipid Science and Technology,* 112(8), pp. 859–870, DOI:10.1002/ejlt.201000076.

Ham Y. K, Song D. H., Noh S. W., Gu T. W., Lee J. H., Kim T. K., Choi Y. S., Kim H. W. (2020), Effects of gelatin hydrolysates addition on technological properties and lipid oxidation of cooked sausage, *Food Science and Animal Resources*, 40(6), pp. 1033-1043, DOI: 10.5851/kosfa.2020.e74.

Henning S. S. C., Tshalibe P., Hoffman L. C. (2016), Physico-chemical properties of reduced-fat beef species sausage with pork back fat replaced by pineapple dietary fibres and water, *LWT—Food Science and Technology*, 74, pp. 92–98, DOI: 10.1016/j.lwt.2016.07.007.

Kim H. W., Choi J. H., Choi Y. S., Han D. J.;, Kim H. Y., Lee M.A., Kim S. Y., Kim C. J. (2010), Effects of sea tangle (*Lamina japonica*) powder on quality characteristics of breakfast sausages, *Korean Journal of Food Science of Animal Resources*, 3(1), pp. 55–61, DOI: 10.5851/kosfa.2010.30.1.55.

Kim T. K., Yong H. I., Jung S., Kim Y. B., Choi Y. S. (2020), Effects of replacing pork fat with grape seed oil and gelatine/alginate for meat emulsions, *Meat Science*, 163, 108079, DOI: 10.1016/j.meatsci.2020.108079.

Knipe L. (1983), Use of phosphates in sausage. Proceedings of the Third Annual Sausage and Processed Meats Short Course, pp. 105-108, https://meatsci.osu.edu/node/125.

Lee C. H., Chin K. B. (2019), Evaluation of physicochemical and textural properties of myofibrillar protein gels and low-fat model sausage containing various levels of curdlan, *Asian-Australasian Journal of Animal Sciences*, 32(1), pp. 144-151, DOI: 10.5713/ajas.18.0585.

Luo H., Guo C., Lin L., Si Y., Gao X., Xu D., Jia R., Yang W. (2020), Combined use of rheology, LF-NMR, and MRI for characterizing the gel properties of hairtail surimi with potato starch. *Food and Bioprocess Technology*, 13(4), pp. 637–647, DOI: 10.1007/s11947-020-02423-y.

Marcos C., Viegas C., de Almeida A. M., Guerra M. M. (2016), Portuguese traditional sausages: different types, nutritional composition, and novel trends, *Journal of Ethnic Foods*, 3(1), pp. 51–60, DOI: 10.1016/j.jef.2016.01.004.

Pintado T., Herrero A. M., Jiménez-Colmenero F., Ruiz-Capillas C. (2016), Strategies for incorporation of chia (*Salvia hispanica* L.) in frankfurters as a health-promoting ingredient, *Meat Science*, 114, pp. 75-84, DOI: 10.1016/j.meatsci.2015.12.009.

Pinton M. B., Correa L. P., Facchi M. M. X., Heck R. T., Leães Y. S. V., Cichoski A. J., Lorenzo J. M., Dos Santos M., Pollonio M. A. R., Campagnol P. C. B. (2019), Ultrasound: A new approach to reduce phosphate content of meat emulsions, *Meat Science*, 152, pp. 88-95, DOI: 10.1016/j.meatsci.2019.02.010.

Ren Y., Huang L., Zhang Y., Li H., Zhao D., Cao J., Liu X. (2022), Application of emulsion gels as fat substitutes in meat products, *Foods*, 11(13), p. 1950, DOI: 10.3390/foods11131950.

Shang F., Kryzhska T., Duan Z. (2022), Study on the effect of baking process on the quality characteristics, moisture distribution and sensory evaluation of bran, duck and pork emulsification sausage, *Eastern-European Journal of Enterprise Technologies*, 1(11 (115)), pp. 41–48, DOI: 10.15587/1729-4061.2022.253210.

Shan L. C., De Brún A., Henchion M., Li C., Murrin C., Wall P. G., Monahan F. J. (2017), Consumer evaluations of processed meat products reformulated to be healthier - A conjoint analysis study, *Meat Science*, 131, pp. 82-89, DOI: 10.1016/j.meatsci.2017.04.239.

Shao J. H., Deng Y. M., Jia N., Li R. R., Cao J. X., Liu D. Y., Li J. R. (2016), Low-field NMR determination of water distribution in meat batters with NaCl and polyphosphate addition, *Food Chemistry*, 200, pp. 308-314. DOI: 10.1016/j.foodchem.2016.01.013.

Sherman R. A., Mehta O. (2009), Phosphorus and potassium content of enhanced meat and poultry products: Implications for patients who receive dialysis. *Clinical Journal of the American Society of Nephrology*, 4(8), pp. 1370-1373, DOI: 10.2215/CJN.02830409.

Stabnikova O., Marinin A., Stabnikov (2021), Main trends in application of novel natural additives for food production, *Ukrainian Food Journal*, 10(3), pp. 524–551, DOI: 10.24263/2304-974X-2021-10-3-8.

Wang P., Xu X., Zhou G. (2009), Effects of meat and phosphate level on water-holding capacity and texture of emulsion-type sausage during storage, *Agricultural Sciences in China*, 8(12), pp. 1475–1481, DOI: 10.1016/s1671-2927(08)60361-2.

Wang J., Hou J., Zhang X., Hu J., Yu Z., Zhu Y. (2022), Improving the flavor of fermented sausage increasing its bacterial quality via inoculation with *Lactobacillus plantarum* MSZ2 and *Staphylococcus xylosus* YCC3, *Foods*, 11(5), p. 736. DOI:

10.3390/foods11050736.
Wang Z., Wang Z., Ji L., Zhang J., Zhao Z., Zhang R., Bai T., Hou B., Zhang Y., Liu D., Wang W., Chen L. (2021), A review: Microbial diversity and function of fermented meat products in China, *Frontiers in Microbiology*, 12, p. 645435, DOI: 10.3389/fmicb.2021.645435.
Xu L., Lv Y., Su Y., Chang C., Gu L., Yang Y., Li J. (2021), Enhancing gelling properties of high internal phase emulsion-filled chicken gels: Effect of droplet fractions and salts, *Food Chemistry*, 367, 130663, DOI:10.1016/j.foodchem.2021.130663.
Yadav S., Pathera A. K., Islam R. U., Malik A. K., Sharma D. P. (2018), Effect of wheat bran and dried carrot pomace addition on quality characteristics of chicken sausage, *Asian-Australas Journal of Animal Science*, 31(5), pp. 729-737. DOI: 10.5713/ajas.17.0214.
Yang H. S., Kim G. D., Choi S. G., Joo S. T. (2010), Physical and sensory properties of low fat sausage amended with hydrated oatmeal and various meats, *Korean Journal for Food Science of Animal Resources*, 30(3), pp. 265–272, Available at: https://pdfs.semanticscholar.org/eb4d/54ae72fd19ffce3febd75b570e645e16859d.pdf.

Effect of complex baking improver on prolonging freshness of bakery products with reduced salt content

Olena Bilyk, Viktor Stabnikov, Oksana Vasheka, Yulia Bondarenko, Oksana Kochubei-Lytvynenko

National University of Food Technologies, Kyiv, Ukraine

Keywords:

Bakery
Lean
Staleness
Improver
Crumb
Additives

Article history:

Received 21.06.2022
Received in revised form 10.09.2022
Accepted 30.12.2022

Corresponding author:

Olena Bilyk
E-mail:
bilyklena@gmail.com

DOI: 10.24263/2304-974X-2022-11-4-9

Abstract

Introduction. The aim of research was to determine the effect of a complex baking improver on prolonging the freshness of bakery products with a reduced salt content using the principles of lean manufacturing.

Materials and methods. Sociological research on the requirements for the quality of bakery products was conducted. A composition of a complex improver "Mineral Freshness Plus” was developed and its optimal dosage was determined. The effects of the developed improver addition on the quality of bakery products with reduced salt content of 0.5% by weight of flour, and the effect on the processes of staling products during storage were studied.

Results and discussion. According to sociological studies the presence of ingredients of synthetic origin in bakery products and rapid loss of their freshness is undesirable for consumers.

To meet the consumer demands, the use of the principles of lean manufacturing in bakery production is provided, which consists in reducing technological costs and losses due to application of the developed improver.

A recipe for a complex baking improver Mineral Freshness Plus has been developed, which is designed to intensify the technological process, improve consumer properties and time for keeping the freshness of bakery products with low salt content of 0.5%. The composition of the improver includes food additives with Generally Recognized as Safe status. Addition of "Mineral Freshness Plus" improver in quality of 2.0% to flour weight extends freshness of bakery products.

This is confirmed by the higher by 65.2–75.6% content of dextrins in the product with the improver comparштп with the control, the thinner subcrustal layer on 72 hours of products storage, and changes in the structure of the bread pulp, which consists of interspersed swollen and partially gelatinized grains of starch, wrapped in a continuous mass of coagulated proteins.

Conclusions. The use of the developed improver "Mineral Freshness Plus” in the manufacture of bakery products ensures the high consumer demands.

Introduction

Bakery products being a part of everyday diet consumption have an important role in human nutrition. To increase the competitiveness of bakery products, manufacturers, through the applicaton of accelerated technologies, food additives, non-traditional raw materials, are expanding the range and providing products.

Hovewer, consumers are dissatisfied with the presence of food additives of synthetic origin in the composition of products, the rapid loss of product freshness, namely the loss of aroma and taste, the elasticity of the crumb and the crunch of the crust (Bilyk et. al., 2019). These changes are caused by the components of formulation, the method of dough preparation, the quality of raw materials, the duration and conditions of storage.

Along with this, to increase the competitiveness of food industry enterprises is the active promotion of the system of operational improvement and optimization of business processes in the company's activities.

The world trend in the business processes management is the use of anti-crisis management systems, among which the most famous is "Economical (lean) production" or "Lean-management". The main goal of lean-management is a creation of needed product value to meet an actual customer’s demands based on the principle of fewer resources and less waste. Thus, the development of complex improvers, which, along with enhancing of the finished products consumer properties, will improve their nutritional value and ensure their economical production, is the actual direction of scientific research in the technology of bakery products.

The formulations of complex bakery improvers consist of a functional and an active part. Functional part includes such ingredients as flour, starch, dextrenized flour, meanwhile the active part consists from gluten oxidizing and reducing agents, enzymes, emulsifiers and various food additives or ingredients with specific effects.

All components of the complex baking improver are selected according to their activity and synergistic action with each other (Bilyk et al., 2019).

The use of complex bakery improvers allows to intensify the technological process, as well as reduce and cost of production and losses during the storage.

The aim of research was to determine the effect of a complex baking improver "Mineral Freshness Plus" on prolonging the freshness of bakery products with a reduced salt content using the principles of lean manufacturing.

Only Generally Recognized as Safe (GRAS) additives will be included in the composition of proposed improver.

Materials and methods

Materials

Preparation of dough samples

Dough samples were prepared according to the recipe, % by weight of flour: premium wheat flour, 100.0, pressed baker's yeast, 3.0, salt, 0.5, margarine, 2.0, sugar, 2.0. The dough with a moisture content of 44.5% was kneaded using a non-dough method. The dough was kneaded in a two-speed Escher kneading machine (Italy). The dough was processed manually, the test pieces were kept at a temperature of (38 ± 2) °C and relative humidity (78 ± 2)%. The products were baked in a Sveba-Dahlen cabinet oven (Italy) at a temperature of 220–240 °C.

Methods

Determination of bread weight, volume and specific volume

The weight of bread was determined after cooling using a digital balance with accuracy 0.01 g, and the bread volume was determined using grain displacement method. The specific volume of each bread was calculated as (Zhu et al., 2016).

Determination of bread porosity

The porosity of bread was determined as the volume of the pores in a certain volume of the crumb, expressed as a percentage to the total volume (Verheyen et al., 2015).

Determination of Comprehensive Quality Score

Based on the results of the sensory and physico-chemical evaluation of finished products, a complex quality index was calculated. The Comprehensive Quality Score is the total number of points a prototype receives when it is analyzed. For its calculation, each product was evaluated according to the following parameters: specific volume; the correctness of the form; crumb color; characteristics of the surface of the crust; bread staling after 72 hours; the porosity structure; form stability of hearth bread; rheological properties of the pulp; the aroma of bread; taste of bread, and crumb chewing.

These bread properties were evaluated on a five-point scale, taking into account the weighting coefficient, which was established for each parameter by the method of expert evaluation. The number of points provided to the parameter was multiplied by the weighting coefficient. Then, the sum of the obtained values was calculated. The more points the sample receives as a result of the calculation, the better its quality.

The expert commission included seven PhD, three Masters of philosophy, and 15 postgraduate students by the specialty "Food Technologies".

Determination of bread pulp deformation

The time for which bread keeps the freshness was evaluated by changing the structural and mechanical properties of the bread pulp. Its total deformation was determined after 48 h of storage using an AP 4/1 penetrometer (Finemass, Germany) (Drobot et al., 2015).

Determination of aromatic substances content

The content of aromatic substances in finished products was evaluated by the amount of bisulfite-binding compounds (Drobot et al., 2015). The method is based on the ability of aldehydes and some ketones react with sodium bisulfite to form adducts, and consists in the preliminary removal of unreacted bisulfite by iodine, followed by the destruction of the adducts with sodium bicarbonate and the dissolution of the released bisulfite, which is equivalent to the content of carbonyl compounds.

Determination of the staling degree

The staling degree of bread was evaluated by area and stiffness of the subcrustal layer using scanning and graphic editors to determine the average thickness of the subcrustal layer (Petrusha and Niemirich, 2016).

Microscopy of bakery products

Microscopy of bakery products was performed after 72 hours of storage. The samples were stored unpackaged at a temperature of (20±0) °C. The samples were prepared by freezing, freeze-drying, and deposition of carbon in a vacuum chamber on a piece of the dried sample. The samples were examined using an IEOLJSMM-200 (Japan) scanning electron microscope at a magnification of 1000 times and the most visible areas were photographed.

Determination of dextrins content

The content of dextrins was determined by the method of their mass fraction, which is based on the ability of dextrins to precipitate at various concentrations of ethanol in solution. Test samples were treated with enzymes to release the sample from water-soluble carbohydrates and fermentable sugars for better recovery. Precipitation of dextrins was carried out with alcohol solutions of different concentrations. Further dissolution of the extracted dextrins was done in water, and they were hydrolyzed with a 2% hydrochloric acid solution. Determination of the amount of glucose in the hydrolyzate of dextrins of different molecular weights was carried out according to the method of Wiltetter and Schudl. On the basis of a certain content of dextrins, the mass fraction of dextrins was determined by fractions, depending on the mass fraction of dextrins in ethyl alcohol solutions with different concentrations (Drobot et al., 2015).

Statistical analysis

All experiments were performed at least in triplicates. The statistical analysis of the data was performed by sequential regression analysis using the Microsoft Excel XP and Origin Pro8 software calculating correlation coefficients (Hinkle et al., 2003).

Results and discussions

Sociological research to found ways to improve bakery products

The first step of the research using the Kano method (Mezur et at., 2017), the requirements for bakery products that consumers expect to improve were studied.Consumers of bakery products were invited to participate in the study. 79 respondents took part in the sociological survey, namely, 27 men aged from 32 to 39 and 52 women aged from 28 to 39 years.All respondent interviews are working people having families of at least 3 people. An analysis of their preferences and characteristics showed that the vast majority of respondents (88.6%) consume products daily and buy bakery products at least 1 time in 3 days and, and 70.9% of respondents prefer products made from wheat flour. When choosing products, consumers pay special attention to: packaging, 64.6%; quantity of products, 62.0%; labeling (primarily information on recommended consumption periods and product composition), 91.1%; the presence of non-traditional flavoring additives (seeds and nuts), dried tomatoes and olives, 87.3%, and useful ingredients in products, 93.4%.

Questionnaires proposed by Noriaki Kano, which allow to separate product requirements into mandatory, expected, attractive, unimportant and undesirable, were used during the surveys,

According to the results of survey, the properties of products required by the current regulatory documentation and the absence or unsatisfactory level of which indicate a poor-quality product are classified as mandatory attributes. Among the requirements of this category, the following characteristics are the most valuable for consumers: the shape, taste and aroma, the state of the crust, the elasticity and porosity of the pulp, and the freshness of the product

Expected or one-dimensional requirements include those whose presence or improvement of which has a linear correlation with customer demands. An analysis of the respondents' answers shows that environmental friendliness of packaging, product availability, small volumes of the product in a unit of consumer packaging, the presence of natural flavoring ingredients in the composition of products, and their high staling resistance are related to this category of requirements.

An attractive feature for the majority of respondents, 93.4%, is a wide range of products of one brand, to meet the needs of all family members. Among the product properties, consumers are particularly interested in such as: reduced calorie content, 53.2%, enrichment of finished products with micronutrients of natural origin, 62.0%, and reduction of salt content in the product, 55.7%.

It was found that such characteristics as the color of the crust and crumbling, when they reach the minimum acceptable level, are unimportant properties, since they do not affect the overall impression from finished product and do not reduce the value of the product for consumers. This is due in large part to the fact that most of the bakery products are packaged, making it difficult for the consumer to evaluate the quality of their surface and crumbliness.

It should be noted that the presence of a pronounced aroma of a fresh bakery product at the stage of staleness creates a negative impression and is associated by the overwhelming majority of respondents with the presence of synthetic flavors in the product. Also, undesirable characteristics of bakery products include the presence of other ingredients of synthetic origin and too bright packaging.

Based on the results of the first step of the research, the feasibility to improve the range of bakery products made from wheat flour was found, the requirements for finished products were grouped, and highly valued by the respondents characteristics were determined. All this allowed to make the description of the desirable finished product.

Development of a composition for a complex baking improver

To develop a complex baking improver for bakery products from premium wheat flour with a reduced salt content the medium-strong flour and selected food additives with the status of GRAS Official website of the US government US Foof & Drug (FAD, 2022) was used to crease the composition of the complex improver were used.

These additives included:

- moisture-containing additives: white clay, apple pectin (Zhang et al., 2021), dry wheat gluten, carboxymethyl cellulose (Ammar et al., 2020), maltodextin (Lauren et al., 2018);
- surface-active substance: phosphatide concentrate (Gómez et al., 2004);
- amylolytic enzymes: enzyme preparation Alfamalt 50 (to ensure the intensity of fermentation and volume of products) (Zhang et al., 2019) and enzyme preparation Novamil 1500 MG (to prolong the freshness of products) (Lambert-Meretei et al., 2010);
- a natural oxidizing agent: ascorbic acid.

Based on the results of trial baking of bakery products from premium flour, made with the addition of different components of a baking improver, Comprehensive Quality Scores were calculated (Table 1).

Table 1

Determination of the optimal addition of components in the baking improver by Comprehensive Quality score

Comprehensive Quality Scores					
Control	**Addition, % of the weight of flour**				
	Pharmaceutical white clay				
	0.5	1.0	1.5	2.0	2.5
88.6	89.4	89.8	90.6	91.2	91.2
	Enzyme preparation Novamil 1500 MG				
	0.004	0.008	0.012	0.016	1.25
88.6	88.8	89.8	90.6	91.8	91.3
	Enzyme preparation Alfamalt 50				
	0.005	0.010	0.015	0.020	0.025
88.6	89.8	90.4	91.6	92.7	92.7
	Dry wheat gluten				
	0.05	0.1	0.15	0.20	0.25
88.6	88.6	89.1	89.5	90.1	90.2
	Carboxymethylcellulose				
	0.005	0.010	0.015	0.020	0.025
88.6	88.6	89.4	90.2	91.7	91.8
	Apple pectin				
	0,01	0.02	0.03	0.04	0.05
88.6	88.6	89.1	89.5	90.1	90.2
	Maltodextrin				
	0.1	0.2	0,4	0.6	0.8
88.6	88.6	89.5	90.6	90.8	90.8
	Phosphatide concentrate				
	0.12	0.18	0.24	0.30	0.36
88.6	88.8	89.2	90.2	90.2	90.3
	Ascorbic acid				
	0.004	0.006	0.008	0.01	0.012
88.6	88.8	89.8	90.6	90.8	90.3

According to the Comprehensive Quality Scores, the rational dosages of the components in the baking improver, % of the weight of flour, are: white clay, 2.0%; enzyme preparation Novamil 1500 MG, 0.016%; enzyme preparation Alfamalt 50, 0.020%; dry wheat gluten, 0.2%, carboxymethylcellulose, 0.02%, apple pectin, 0.04%, maltodextrin, 0.4%, phosphatide concentrate, 0.24; ascorbic acid, 0.008% (Table 1). When formulating a baking improver, the found rational dosage of food additives and food ingredients was halved to form an improver recipe.

As a result of the research, a recipe for a complex baking improver (CBI), Mineral Fresh Plus, to intensify the technological process, improve consumer properties and lengthen the freshness of bakery products with low salt content of 0.5% was developed (Table 2).

Table 2

Recipe of complex baking improver (CBI) Mineral Freshness Plus

Additives	Raw materials, kg/ 100 kg of CBI
Pharmaceutical white clay	81.0
Enzyme preparation Novamil 1500 MG	0.3
Enzyme preparation Alfamalt 50	0.4
Dry wheat gluten	4.0
Carboxymethylcellulose	0.4
Apple pectin	0.8
Maltodextrin	8.0
Phosphatide concentrate	4.9
Ascorbic acid	0.2
Total	100

To determine the influence of CBI addition on the quality of finished bakery products with low salt content of 0.5%, laboratory baking with the dosage of CBI 1.0; 1.5; 2.0, and 2.5% by weight of flour were conducted (Table 3).

Table 3

Influence of a complex baking improver on the technological process and product quality

<table>
<tr><th rowspan="2">Characteristics</th><th rowspan="2">Control (no CBI)</th><th colspan="4">CBI addition, % of the weight of flour</th></tr>
<tr><th>1.0</th><th>1.5</th><th>2.0</th><th>2.5</th></tr>
<tr><td colspan="6">Sensory indicators</td></tr>
<tr><td>Shape</td><td colspan="5">Oblong, oval, not indistinct, the incisions are clear</td></tr>
<tr><td>Crust color</td><td>Light</td><td>Light golden</td><td colspan="3">Golden to brown</td></tr>
<tr><td>Crust surface condition</td><td colspan="3">Quite smooth, single small bubbles, barely noticeable small short cracks and explosions, glossy</td><td colspan="2">Perfectly smooth, without bubbles and cracks, undermining, glossy</td></tr>
<tr><td>Porosity structure</td><td colspan="5">The pores are small, thin-walled and medium, distributed fairly evenly</td></tr>
<tr><td>Aroma</td><td colspan="5">Intensely pronounced, typical for bakery products</td></tr>
<tr><td>Taste</td><td>Peculiar to bakery products, not salty</td><td colspan="4">Intensely pronounced, characteristic of bakery products</td></tr>
<tr><td>Specific volume, cm^3/100 g</td><td>328</td><td>340</td><td>352</td><td>368</td><td>376</td></tr>
<tr><td>Form stability, h/d</td><td>0.51</td><td>0.8</td><td>0.45</td><td>0.45</td><td>0.45</td></tr>
<tr><td>Porosity, %</td><td>72</td><td>82</td><td>84</td><td>88</td><td>90</td></tr>
<tr><td>Acidity, degree</td><td>1.2</td><td>1.8</td><td>2.0</td><td>2.0</td><td>2.2</td></tr>
<tr><td>Preservation of freshness</td><td>42</td><td>52</td><td>55</td><td>70</td><td>70</td></tr>
</table>

An increase of the specific volume of bakery products with low salt content of 0.5% is due to the introduction of amylolytic enzymes into the test system with CBI, which intensifies the fermentation process due to additional nutrition for yeast, and improved dough elasticity due to the action of phosphatides.

For further studies of the effect of the developed complex baking on the quality of finished bakery products with low content of salt, 0.5% by weight of flour, a dosage of CBI 2.0% by weight of flour was chosen.

Influence of the complex baking improver Mineral freshness Plus on the quality and preservation of freshness of a bakery products with a reduced salt content

The assimilation of bakery products largely depends on their taste and aroma. These indicators are formed during dough preparation and baking. The formation of compounds that affect taste and aroma depends on the composition of the recipe and the products of the interaction of sugars, carbonyl compounds with amino acids and proteins.

The main compounds that form the aroma of bakery products are carbonyl containing substances. A recognized method for studying the aroma of products is the determination of the content of carbonyl compounds (Table 4).

Table 4

Content of bisulfite-binding substances, mg-eq/100 g of a bakery product

Part of bakery product	Control (no CBI)	With CBI
after 4 hours of storage		
Pulp	8.6	15.4
Crust	24.3	28.2
after 24 hours of storage		
Pulp	7.1	13.,2
Crust	20.5	26.1
after 48 hours of storage		
Pulp	5.3	10.4
Crust	17.3	21.1
after 72 hours of storage		
Pulp	4.2	7.5
Crust	13.4	16.8

It was shown that when the developed complex baking improver was added to the dough, the content of carbonyl compounds in the crumb and crust of the bakery product increased by 1.6-4.2 times (Table 4). This is due to the fact that complex baking improver contains an amylolytic enzyme preparations and maltodextrin, which accelerate the process of dough fermentation, maturation of dough pieces and the accumulation of aromatic substances, as well as due to addition of carbonyl containing substances such as apple pectin and phosphatide concentrate.

An increase of the content of carbonyl compounds in finished products with an improver correlates with an enhancement of the crust color and the aroma of bread. Addition of complex baking improver does not change the traditional taste of finished products, despite the reduction in the salt content.

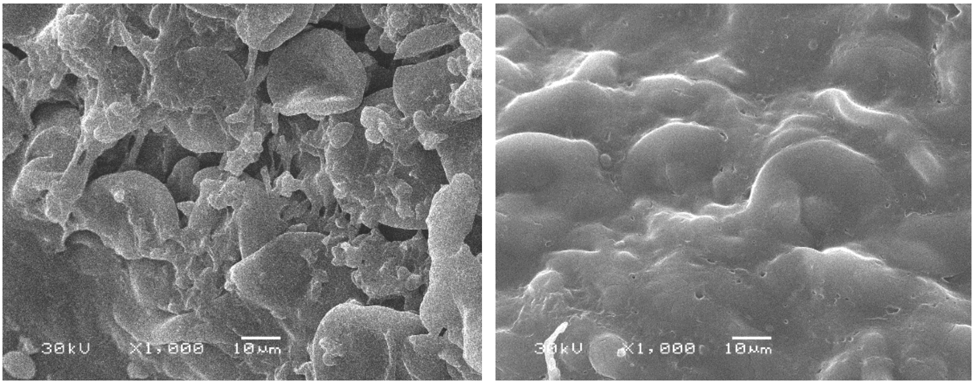
Analysis of the research results showed that the addition of the developed complex baking improver in bakery product has a positive effect on the preservation of the bakery product freshness and the subcrustal layer of bakery product after 72 hours of storage is thinner compared to the subcrustal layer of the control (Figure 1).

a b

Figure 1. The subcrustal layer of bakery product after 72 hours of storage: a, control (no CBI); b, with CBI Mineral Freshness Plus

After scanning and measuring of the thickness of the subcrustal layer of the bakery product, it was found that in the control sample the subcrustal layer after 7 hours of storage was 5.43 mm, and when using the Mineral Freshness Plus, it was 3.02 mm.

The bakery samples were stored unpackaged at a temperature of (20±2)°C. Microstructure of bakery products after 72 hours of storage were studied using scanning electron microscope at a magnification of 1000 times (Figure 2).



a b

Figure 2. Microstructure of bakery products after 72 hours of storage: a, control (no CBI); b, with CBI Mineral Freshness Plus

The results of the studies showed that in bakery products with the complex baking improver, the crumb of products consists of interspersed swollen and partially gelatinized starch grains, wrapped in a continuous mass of coagulated proteins, and only in some places air layers are visible (Figure 2b). In the control sample, on the contrary, the crumb was characterized by the presence of voids between the pores, which confirms the formation of the starch crystal structure and protein compaction during storage (Figure 2a).

When storing bakery products, the structural and mechanical properties of their crumbs are changed. Changes of the product crumb were determined by its deformation after 4 and 72 hours of storage using a penetrometer. Improving the deformation characteristics of bakery products when using the complex baking improver is due to the introduction of proteins from the CBI into the dough system, which strengthen the structure of the pulp of product because of strengthening of hydration ties and prevention starch from losing moisture during product storage (Table 5).

Table 5

Deformation of bread pulp during product storage

Samples of bread, time of storage	Type of deformation, units of device			Preservation of freshness, %
	total	plastic	elastic	
4 hours of storage				
Control (no additives)	82	53	29	
With CBI Mineral Freshness Plus	114	79	35	
72 hours of storage				
Control (no additives)	34	20	14	**41.5**
With CBI Mineral Freshness Plus	82	51	31	**71.9**

Apple pectin and maltodextrin present in the complex baking improver also possess the moisture-retaining capacity. Along with this, maltodextrin is a water-soluble hydrocolloid that increases the level of moisture retention and forms a three-dimensional network, which inhibits the interaction of gluten and starch resulting in slower retrogradation of starch. When maltogenic α-amylase is added to the dough, the rate of recrystallization of the amylopectin fraction of starch decreases, which delays its retrogradation. This process also prevents complex formation between the polar group of the phosphatide concentrate and the amylose fraction of the starch, which reduces the rate of retrogradation.

It is known that the addition of amylolytic enzymes to the dough increases the rate of fermentation and leads to the formation of a sufficient amount of sugars. Due to additional sugars, the porosity of bakery products becomes more thin-walled, homogeneous, which helps to improve their taste, crust color, and long-term preservation of freshness. The use of dextrins also improves the quality of bakery products and the duration of freshness.

Due to the fact that starch is degraded during the baking process and given that the complex baking improver includes maltogenic α-amylase, carboxymethylcellulose, apple pectin, and maltodextrin, it was advisable to study the change in the amount of dextrins in bakery products.

During baking of bakery products, starch is destroyed with the formation of dextrins. The total amount of dextrins increases by 65.2–75.6% when using CBI compared with the control due to the action of maltogenic α-amylase, which hydrolyzes starch to dextrins, and the direct introduction of maltodextrin (Table 6).

Table 6

Content of dextrins in bakery products

Bakery products	Content of dextrins by fractions, % of DW			Content of total dextrins
		erythro-dextrins	malto- and acro-dextrins	
Control (no CBI)	0.802	0.288	0.701	1.791
With CBI Mineral Freshness Plus	1.127	0.408	1.198	2.733

As a result of the the complex baking improver addition, an increase in low molecular weight dextrins, namely, maltodextrins and achrodextrins, is observed.

So, in the bakery product with CBI, the amount of low molecular weight dextrins increases by 2.5 times. In this regard, the process of staleness of bakery products slows down due to the formation of a three-dimensional network by low molecular weight dextrins, which prevents the interaction of gluten and starch and the release of moisture by starch.

Construction and analysis of the matrix "House of Quality" on the use of the developed improver in the production of a bakery product

In a number of international publications, teams of scientists and practitioners present the results of the successful use of the QFD methodology in order to improve products in accordance with the requirements and expectations of consumers (Lo et al., 2017; Mardar et al., 2016). The deployment of quality functions and the construction of the first-level "House of Quality" matrix ensures the implementation of the "voice of the client" regarding the expected improvements, establishes a close relationship between the wishes of consumers and the technical characteristics of products, determines the priority of their implementation (Chaudha et al., 2011). Therefore, at the next step, during the re-questioning of respondents and ranking the attributes of the experimental product model, we studied their significance for potential consumers (Shrivastava et al., 2016).

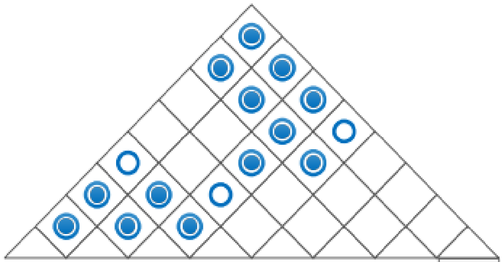
100 people were involved in the survey. The data obtained are given in the part of the requirements of the customers of the "House of Quality" relationship matrix in Figure 3.

Taking into account the importance for consumers of each of the specific requirements and focusing on their achievement at the maximum level, the relative weights of the properties are calculated. The ranking of requirements indicates that the most expected product characteristics for consumers are the reduction of calorie content of bakery products and the expansion of their range through the use of new flavoring ingredients. A group of properties that can be attributed to the unconscious characteristics of products and have a significant impact on the formation of consumer demands is the enrichment of products with natural micronutrients and the reduction of salt in their composition. The high values of the relative weight of such attributes as freshness (8%), taste and aroma during storage (7.8%), and product information shown in the product labeling (7.8%) indicate their decisive role in shaping the overall impression of product quality.

The attributes indicated by consumers are analyzed and their connection with the peculiarities of the formation of sensory and physico-chemical characteristics of finished products, the technical features of production, the complexity of implementing innovations in the production environment are found.

The analysis showed that one of the promising areas for achieving the improvements expected by consumers is the use of the complex baking improver Mineral Freshness Plus. The strong relationship between a number of customer requirements and CBI use determines the feasibility and high priority of this implementation (23.8%).

It should be noted that, according to the production workers, the complexity of implementing the requirements at the enterprise is rated at an average level, namely 3 points. This indicates that the use of the improver will not cause significant efforts to change the technological parameters of the process, special equipment readjustment and long-term training of personnel in its application.



Degree of connection

- ● strong connection
- ○ medium connection
- \+ weak connection

	weighting of consumer responses	raw material quality	formulation (number and ratio of components)	organization of technological processes	additional raw material	type of packaging	product weight	improver Mineral freshness	flavor fillers	Relative importance of properties, %
aroma and taste	4,43	●	●	●	●			●	●	7,8
shape	3,99	●	+	○	○			●		7,0
crust condition	4,10	●	●	●	●			●	○	7,2
elasticity and porosity of the pulp	4,30	●		●	●			●		7,6
product freshness	4,51	●		●	●	●	●	●		8,0
environmental friendliness of packaging	4,09					●				7,2
product availability	3,95						●	○	○	7,0
weight per packing unit	4,23					●	●			7,5
natural flavor ingredients	4,73		○					●	●	8,4
reduced calorie content	4,88		○					+	●	8,6
reduced salt content	4,48							●		7,9
enrichment with natural micronutrients	4,50							●	○	7,9
marking	4,43					●				7,8
Complications in implementing requirements		5	1	2	1	2	2	3	2	
Implementation priority, %		14,9	10,5	12,2	12,2	10,7	7,9	23,8	7,6	

Figure 3. The matrix "House of Quality" on the use of the developed improver in the production of a bakery product

So, based on the results of a survey of consumers using the "House of Quality" matrix, the ranking of product attributes was carried out and their dependence on the technical characteristics of finished products was found, measures were identified to achieve the most significant needs for customers. The priority of using in the bakery technology developed the complex baking improver Mineral Freshness Plus was proved, which will ensure the achievement of a number of conscious and unconscious needs of consumers, and, accordingly, the formation of high customer satisfaction.

Conclusions

1. A sociological study identified the criteria for the quality of bakery products, the improvement of which is expected by consumers: reducing the calorie content of products, enriching products with micronutrients of natural origin, and reducing the salt content in products. Undesirable characteristics of products by consumers were noted by the presence in the composition of ingredients of synthetic origin and the rapid loss of freshness by products.
2. For the production of a bakery product that meets the expectations of the consumer, the application of the principles of lean-production is provided, which consists in reducing technological losses and costs in the production and storage of products and is achieved by using complex baking improvers.
3. A recipe for the complex baking improver Mineral Fresh Plus has been developed, which is designed to intensify the technological process of production, improve consumer properties and time for keeping the freshness of bakery products with low salt content 0.5%. The composition of the improver includes food additives with GRAS status, that is, safe.
4. In the manufacturing of a bakery product, in the recipe of which the salt content is 0.5% of the weight of flour, it is advisable to use the developed improver Mineral Freshness Plus in the amount of 2.0% by weight of flour. This helps to improve the quality of products and does not change the traditional taste of finished products, despite the reduction of salt content.
5. The use of the developed complex baking improver Mineral Fresh Plus prolongs the time for freshness preservation by bakery products. This is confirmed by the greater content of dextrins in the product with the improver, by 65.2-75.6%, compared to the control, the thinner subcrustal layer after 72 hours of product storage, and changes in the structure of the pulp, consisting of interspersed swollen and partially gelatinized starch grains, which are wrapped with a continuous mass of coagulated proteins.
6. The construction and analysis of the "House of Quality" matrix confirmed that the use of the complex baking improver Mineral Fresh Plus in the manufacturing of bakery products ensures the achievements of high consumer satisfaction.

Acknowledgements. The research was carried out under the auspices of the Grant Agreement 620521-EPP-1-2020-1-UA-EPPJMO-MODULE between the Executive Agency for Education, Audiovisual and Culture of the European Commission and the National University of Food Technologies for the implementation of the Jean Monnet Module project called "Regulation of the use of food additives in various technologies and the harmonization of European regulations in Ukraine on the path of European integration" of the European Union Erasmus + program.

References

Ammar Al-F., Siddeeg A., Aqlan F.M., Howladar S. M., Refai M. Y., Afifi M., Ali H.A., Hajjar D., Sulamain M. G. M., Chamba M. V. M., Kimani B. G., Salehh A., Baeshenc M. (2020), Shelf life extension of wheat bread by alhydwan flour and carboxymethylcellulose and improvement of their quality characteristics, dough rheological and microstructure, *International Journal of Biological Macromolecules*, 156, pp. 851–857, DOI: 10.1016/j.ijbiomac.2020.04.023

Bilyk O., Bondarenko Y., Kochubei-Lytvynenko O., Khalikova E., Fain A. (2019), Studying the effect of the integrated bread baking improver “Mineral Freshness Super” on consumer properties of wheat bread, *Eastern-European Journal of Enterprise Technologies*, *2*(11(98), pp. 65–72, DOI: 10.15587/1729-4061.2019.162671

Chaudha A., Jain R., Singh A. R., Mishra P. K. (2011), Integration of Kano’s Model into quality function deployment (QFD), *The International Journal of Advanced Manufacturing Technology*, *53*, pp. 689-698, Available at: https://www.semanticscholar.org/paper/Integration-of-Kano%E2%80%99s-Model-into-quality-function-Chaudha-Jain/7e3fd3688a9a79262a56392b8dccd37c6b1b1435

Drobot V., Yurchak V., Bilyk O., Bondarenko Y., Gryshchenko A. (2015), *Technochemical control of raw materials and bakery and pasta*, Condor, Kyiv.

FAD (2022), *US Foof & Drug administration. Generally Recognized as Safe (GRAS)*, Available at: https://www.fda.gov/food/food-ingredients-packaging/generally-recognized-safe-gras

Gómez M., Silvia del Real, Rosell C. M., Ronda F., Blanco C.A., Caballero P.A. (2004), Functionality of different emulsifiers on the performance of breadmaking and wheat bread quality, *European Food Research and Technology*, 219, pp. 145–150, DOI: 10.1007/s00217-004-0937-y

Hinkle D. E., Wiersma W., Jurs S. G. (2003), *Applied statistics for the behavioral sciences*, Mass: Houghton Mifflin, Boston, DOI: 10.1016/B978-0-12-824135-6.00030-1

Lambert-Meretei A., Szendrei E., Nogula-Nagy M., Fekete A. Methods to evaluate the effects of bread improver additive on bread crumb texture properties, *Acta Alimentaria*, 2010, 39(2), pp. 180–191, DOI: 10.1556/aalim.39.2010.2.10

Lo S. M., Shen H., Chen J. C. (2017), An integrated approach to project management using the Kano model and QFD: an empirical case study, *Total Quality Management & Business Excellence*, 28, pp. 1584–1608, DOI: 10.1080/14783363.2016.1151780

Mardar M., Zhygunov D., Znachek R. (2016), QFD methodology to develop a new healthconducive grain product, *Eastern-European Journal of Enterprise Technologies*, 2/11(80), pp. 15–20, DOI: 10.15587/1729-4061.2016.65725

Mezur G.H. (2017), *Transitioning from JIS Q 9025 to ISO 16355. 23-rd International QFD Symposium, ISQFD 2017,* Tokyo, pp. 20–42, Available online: https://static1.squarespace.com/static/5eb315d2b0e6914ba0419e47/t/5eb9f5795f22c75dffa4fbb8/1589245309034/mazur_2017_transitioning_from_jis_9025_to_iso_16355.pdf

Petrusha O., Niemirich A. (2016), Assessment of color of meat using the method of computer colorimetry, *Eureka: Life Sciences*, 3, pp. 3–7, DOI:10.21303/2504-5695.2016.00141

Shrivastava P. (2016), House of quality: An effective approach to achieve customer satisfaction and business growth in industries, *International Journal of Science and Research*, 5(9), pp. 1365–1371, Avalable at: https://www.ijsr.net/archive/v5i9/ART20161787.pdf

Tebben L., Shen Y., Li Y., (2018), Improvers and functional ingredients in whole wheat bread: A review of their effects on dough properties and bread quality, *Trends in Food Science & Technology*, 81, pp. 10–24, DOI: 10.1016/j.tifs.2018.08.015

Verheyen C., Albrecht A., Elgeti D., Jekle M., Becker T. (2015), Impact of gas formation kinetics on dough development and bread quality, *Food Research International*, 76(3), pp. 860–866, DOI: 10.1016/j.foodres.2015.08.013

Zhang L., Li Z., Qiao Y., Zhang Y., Zheng W., Zhao Y., Huang Y., Cui Z. (2019), Improvement of the quality and shelf life of wheat bread by a maltohexaose producing α-amylase, *Journal of Cereal Science*, 87, pp. 165–171, DOI: 10.1016/j.jcs.2019.03.018

Zhang X., Li J., Zhao J., Mu M., Jia F., Wang Q., Liang Y., Wang J. (2021), Aggregative and structural properties of wheat gluten induced by pectin, *Journal of Cereal Science*, 100, pp. 103247, DOI: 10.1016/j.jcs.2021.103247

Zhu F., Sakulnak R., Wang, S. (2016), Effect of black tea on antioxidant, textural, and sensory properties of Chinese steamed bread, *Food Chemistry*, 194, pp. 1217–1223, DOI: 10.1016/j.foodchem.2015.08.110

Use of bioactive properties of plant extracts to increase the storage stability of mechanically separated turkey meat

Vasyl Pasichniy[1], Vasyl Tischenko[2], Natalia Bozhko[3], Olga Koval[1], Andrii Marynin[1]

1 – National University of Food Technology, Kiyv, Ukraine
2 – Sumy National Agrarian University, Sumy, Ukraine
3 – Sumy State University, Sumyl, Ukraine

Abstract

Introduction. The research aimed to study the influence of natural antioxidants present in black chokeberry, cranberry, and black currant leaf extracts to stabilize the oxidation processes in mechanically separated turkey meat (MSM) during storage.

Materials and methods. The subject of the study was mechanically separated turkey meat. Plant extracts of black chokeberry (*Aronia melanocarpa*) pomace, cranberry (*Vaccinium Oxycoccus)* pomace, and blackcurrant (*Ribes nigrum L.*) leaf were used as antioxidants. During the storage of the turkey MSM the dynamics of oxidation processes were studied and the acid value, peroxide value, and the content of thiobarbituric acid reactive substances were determined.

Results and discussion. The chemical composition of turkey MSM included proteins, 14.22%, and fat, 17.3% that increases the risk of its oxidative deterioration during sale and storage. The use of plant extracts reduced the intensity of lipid oxidation in mechanically separated turkey meat during 9 weeks of frozen storage. At the end of the experiment, the content of free fatty acids in the control sample was the highest and amounted to 3.81±0.02 mg KOH, which is by 131.83% higher than in the sample with blackcurrant leaf extract, 4.76 times higher than in the sample with cranberry extract, and 7.33 times higher than in the sample with black chokeberry extract. The addition of extracts from black chokeberry and cranberry slow down the hydrolytic changes of product fats by 81.20 and 76.47%, respectively. The addition of black chokeberry and cranberry extracts at an amount of 0.2% contributed to the reduction of the peroxide value after two months of storage of mechanically separated turkey meat to 0.057–0.060 J_2 %, which almost halved the synthesis of peroxides in the product. It was shown that the introduction of black chokeberry and cranberry extracts in a content of 0.2–0.3% inhibits the accumulation of secondary lipid oxidation products by 35.10–39.36%.

Conclusion. Comparative analysis and comprehensive assessment of the oxidation product content in control and experimental samples of mechanically separated turkey meat testify the addition of natural antioxidants reduces the oxidative deterioration of turkey MSM under the frozen storage.

Keywords:

Turkey
Meat
Black chokeberry
Cranberry
Blackcurrant
Antioxidant

Article history:

Received 21.10.2022
Received in revised form 14.12.2022
Accepted 30.12.2022

Corresponding author:

Vasyl Pasichniy
E-mail: Pasww1@ukr.net

DOI: 10.24263/2304-974X-2022-11-4-10

Introduction

Modern resource-saving technologies in the poultry processing ensure its fullest use. When separating pieced meat, part of the muscle tissue (35–40% of the bone mass) remains on the bones. It must be further separated to obtain meat of mechanical collapse, which is a paste-like mass without bones and cartilage. The mechanical separation of meat and bone remains is carried out with the aim of obtaining protein-containing raw materials, in particular mechanically separated poultry meat (MSM), similar in physical and chemical properties to minced poultry, separated from bones manually. However, MSM contains a lot of bone and connective tissue, bone marrow, and fat (Massingue et al., 2018).

MSM, obtained from a cooled carcass of poultry or its parts by the separation or pressing in the form of a minced (paste-like) mass, has a standardized amount (not more than 0.6%) and the size of bone tissue (not more than 0.5 mm) and calcium (no more than 0.3%) (Tasić et al., 2017; Komrska et al., 2011). MSM contains up to 15% protein, making it a popular ingredient in the production of emulsified products. Such minced meat is ideal as a component of recipes, which reduces the cost of products both in combination with beef and pork meat, and on its own. The including of 10–15% of mechanically separated turkey meat in the recipes of emulsified meat-containing food products makes it possible to obtain food products with high sensory parameters, which increases their consumer value (Al-Ghayat et al., 2020; Łaszkiewicz et al., 2021).

The authors (Bozhko et al., 2019a; Tischenko et al., 2019) evaluated the possibilities of using mechanically separated turkey meat in the recipes of meat-containing chopped semi-finished products and cooked sausages. Studies have shown that combining raw materials from poultry meat of different levels of nutritional value allows to obtain meat-containing systems with high functional and technological characteristics.

Along with this, the use of turkey MSM both for sale in the form of minced meat and as a recipe component has a number of negative aspects. According to (Ribeiro et al., 2019; Trindade et al., 2008), the main problem of MSM is its tendency to spontaneous autoxidation, which can be observed already on the first day of storage, causing undesirable changes later.

Substances formed during the oxidation of lipids not only deteriorate the quality characteristics of meat products, but are also capable of causing significant harm to human health (Pérez-Palacios et al., 2020). Furthermore, low microbiological resistance and a specific red color (from bright to dark) are reported, which is due to technological factors of production and biochemical properties of MSM turkey (Takács et al., 2020; Wu et al., 2022).

Changes that impair the quality and safety of MSM and meat products using it can be limited by the application of antioxidants and preservatives. However, due to the distrust of consumers in the use of synthetic additives in the production of food products, the search for the possibility of replacing them with plant ingredients with proven antioxidant and antibacterial properties is being conducted (Ivanov et al., 2021; Munekata et al., 2020; Stabnikova et al., 2021). Ingredients such as dried and ground herbs, as well as essential oils or extracts obtained using various solvents, can be incorporated into meat products in a variety of forms (Estévez, 2021; Pateiro et al., 2021).

The aim of the research was to study the effect of natural antioxidants, namely, black chokeberry extract; cranberry extract; blackcurrant leaf extract to slow down the oxidation processes in the turkey MSM fat complex during its storage.

Materials and methods

Experimental design

The subject of the research was mechanical separated turkey meat. To study the effect of natural antioxidants on the oxidative and hydrolytic deterioration of fat in MSM turkey, selected plant extracts were added to freshly prepared minced meat (t = 0 - +4˚C) during mixing on a high-speed cutter (GoodFood C6VV). The selection of the natural antioxidants concentration was carried out based on the results of previous studies and literature data.

As antioxidants, commercial plant extracts, such as black chokeberry (*Aronia melanocarpa*) pomace extract (EBCP); extract from cranberry (*Vaccinium oxycoccus)* pomace (ECP); black currant (*Ribes grum L.*) leaf extract (EBCL) were used in the study (Figure 1).

a **b** **c**

Figure 1. Black chokeberry (a); cranberry (b), and blackcurrant leaf (c)

The extracts were added in the amounts of 0.02% or 0.03% to the mass of raw materials for the experimental samples of minced meat. A sample of minced meat without the addition of an antioxidant was used as a control. The prepared samples were stored at a temperature minus 18 °C for 60 days.

Determination of moisture content

Moisture content was determined by the method of drying (ISO 1442, 2008). 5 g of the sample was placed in a container, dried for 1 hour at 150°C.

Determination of raw protein content

Protein measurements were performed using the Kjeldahl method (ISO 937, 2007). 5 g of homogeneous fillet with 20 mL of concentrated sulfuric acid and 8 g of catalysts were placed in a special container and then heated at 350 °C for 30 min. After mineralization, the sample was quantitatively transferred to a solution of NaOH at a concentration of 33%, sealed, and distilled off with the steam. The resulting steam distillate was transferred to a container containing several drops of the Tashiro indicator. The titration was performed with a solution of 0.01 N sulfuric acid.

Determination of raw fat content

Content of total fat was determined by the Soxhlet method (ISO 1443, 2008). 4 g of the dried sample in a paper cartridge was placed in an extraction flask of a Soxhlet apparatus. Petroleum ether with a boiling point of 45 °C was used for the extraction. After multiple extractions, the constant weight of the test cartridge was determined. The difference between the initial and final weight shows the percentage of fat.

Determination of ash content

Ash content was determined by heating sample overnight at 520°C in a muffle furnace. The sample was weighed before and after heating to determine the content of ash. The ash content was calculated by the formula:

$$Ash = M_{ash}/M_{dry} \times 100, \quad (1)$$

where M_{ash} is the mass of the ashed sample, M_{dry} is the initial mass of the dried sample.

Lipid oxidation determined by acid value, peroxide value, and the content of thiobarbituric acid reactive substances

The acid value was determined by the batch titration with sodium hydroxide in the concentration in the presence of phenolphthalein alcohol solution (Bozhko et al., 2019b). 3–5 g of the sample was weighted in the conic retort with the volume of 150–200 cm^3 with the error of no more than 0.001 g. The batch was heated on the water bath and, after the addition of 50 cm^3 of neutralized ether-alcohol mixture, was shaken. Then 3–5 drops of phenolphthalein alcohol solution with the mass share of 1 % were added. The received solution while shaking was titrated fast with potassium hydroxide solution with the molar concentration 0.1 mol/dm^3 until the distinct rose coloration appeared and kept for 1 min. The acid value was calculated by the formula:

$$X = (V \times K \times 5.61)/m, \quad (2)$$

where V is volume of potassium hydroxide solution, with the molar concentration 0.1 mol/dm^3, used for titration; K is correction to alkali solution for recalculation on the distinct (0.1 mol/dm^3) one; 5.61 is number of milligrams of potassium hydroxide, contained in 1 cm^3 (0.1 mol/dm^3) of solution; m is forcemeat batch mass, g.

The method of peroxide value determination is based on the batch extraction by the mixture of chloroform and icy acetic acid and further titration by the sodium hyposulfite solution with the previously added starch solution (Bozhko et al., 2019b). 0.8–1.0 g of a batch, weighted with accuracy of no more than 0.0002 g were placed in the conic retort with the stopper, melt on the water bath and 10 cm3 of chloroform and 10 cm^3 of icy acetic acid were gently poured on the retort sides. 0.5 cm3of saturated, freshly prepared potassium iodine solution was quickly added. The retort was closed with the stopper; the content was mixed by turning movements and put into the dark place for 3 minutes. Then 100 cm^3 of distilled water with the previously added 1 cm^3 of starch solution with the mass share of 1% was gently poured into the retort. After that it was titrated with sodium hyposulfite solution with the molar concentration of 0.01 mol/dm^3 until the blue color will disappear.

To verify the clearness of reagents the control determination without a batch was realized. The peroxide value was calculated by the formula:

$$X = (V–V_1) \times K \times 0.00127 \times 100/m, \qquad (3)$$

where V is a volume of sodium hyposulfite solution with the molar concentration 0,01 mol/dm^3, used for titration in the main experiment with the forcemeat batch, cm^3; V1 is a volume of sodium hyposulfite solution (0.01 mol/dm^3), used for titration in the control experiment without a forcemeat batch, cm^3; K is coefficient of correction to sodium hyposulfite for recalculation on the distinct (0.01 mol/dm^3) solution; 0.00127 is a number of grams of iodine, equivalent to 1 cm^3 (0.01 mol/dm^3) of sodium hyposulfite; m is a mass of the studied forcemeat batch, g.

The content of thiobarbituric acid reactive substances was determined by measuring the coloration intensity of the mixture of the studied sample distillate and thiobarbituric acid solution (1:1) after 35 minutes on the water bath on the spectrophotocolorimeter "Spекol-11" (Germany) at the wave length 535 nm (Bozhko et al., 2020). 50 g of forcemeat batch were put into the porcelain mortar, 50 cm^3 of distilled water were measured by the glass cylinder, added to the mortar and ground with the pestle into the uniform mixture. The prepared sample was quantitatively transferred into Kjeldahl retort, remains were washed away from the mortar with 47.5 cm^3 of distilled water and then 2.5 cm^3 of hydrochloric acid were added. The distillation was carried out in Kjeldahl apparatus, collecting 50 cm^{3}of distillate in the volumetric flask. 5 cm^3 of distillate were taken, poured into the retort with the fitted stopper. After the addition of 5 cm^3 of thiobarbituric acid, the retort was closed with the fitted stopper and heated on the boiling water bath for 35 min. Simultaneously, the control was hold, using 5 cm^3 of distilled water instead of the distillate. Then the solutions were cooled in the cold running water for 10 min, and the optic density at the wave length of 535±10 nm as to the control solution was measured.

The content of thiobarbituric acid reactive substances, mg of MA (malonic aldehyde)/kg of the product, was calculated by the formula:

$$X = D \times 7.8, \qquad (4)$$

where D is an optic density of the solution; 7.8 is a coefficient of proportional dependency of MA density on its concentration in the solution. This coefficient is a permanent value.

Statistical analysis

The absolute error of measurements was determined by Student criterion, the reliable interval P = 0.95, the number of repetitions in calculations was 3−4, the number of parallel tests of studied samples was 3.

Results and discussion

The characteristics of turkey MSM is shown in Table 1.

Table 1

Characteristics of turkey MSM

Sample	Mousture, %	Protein, %	Fat, %	Ash, %
MSM of turkey	67.83±1.10	14.22±0.97	17.3±0.64	0.50±0,01

The moisture content in mechanically separated turkey meat was 67.83±1.10% that meets the standardized requirements for moisture content less than 70% in MSM. It was found that the mass fraction of crude protein in turkey MSM was 14.22±0.97%, which meets a standard that defines the protein content in MSM not lower than 12%. The fat content in turkey MSM corresponded to the standard and was 17.3±0.64%. A sufficiently high content of protein and fat increases the risk of oxidative deterioration of MSM during the sale of both a separate product and as an ingredient for the production of other meat products.

It has been found that the fatty acid profile of turkey MSM is further formed from lipids present in bone marrow and bone tissue, subcutaneous adipose tissue, skin and abdominal fat (Huang et al., 2019). The higher content of polyunsaturated fats in the fat fraction is due to their intake from bone particles and the spinal cord. Unsaturation of fat determines the degree of its reactivity to oxygen and free radical oxidation (Püssa et al., 2009).

Furthermore, MSM contains heme pigments that are involved in the catalysis of lipid oxidation associated with the formation of highly reactive heme pigment derivatives such as non-protein bound heme iron (hemin, hematin, and heme) and hypervalent heme pigments (Yin et al., 2017). The quality of raw meat is important for the oxidative change of meat after cooking, because primary oxidation products or oxidized lipids from raw meat can continue the oxidation process after heat treatment. The formation of free fatty acids in raw materials, which are formed as a result of hydrolytic deterioration of fats, was determined by the acid value during storage of turkey MSM without plant antioxidants and with plant extracts added to a content of 0.2% (Table 2).

Table 2

Dynamics of the acid value of turkey MSM with 0.2% of plant extracts during the storage, mg KOH

Storage time, weeks	Control sample	EBCP0.2	ECP0.2	EBCL0.2
0	0.25±0.07	0.25±0.02	0.25±0.11	0.25±0.01
1	0.41±0.07	0.26±0.11	0.27±0.03	0.39±0.03
2	0.61±0.03	0.31±0.03	0.30±0.11	0.51±0.01
3	0.98±0.04	0.31±0.03	0.32±0.07	0.90±0.03
4	1.87±0.03	0.35±0.03	0.44±0.20	1.65±0.53
5	2.07±0.02	0.37±0.11	0.71±0.11	1.78±0.06
6	2.31±0.01	0.42±0.03	0.73±0.01	2.09±0.08
7	2.31±0.07	0.49±0.13	0.78±0.01	2.31±0.07
8	3.43±0.02	0.52±0.01	0.78±0.17	2.37±0.03
9	3.81±0.02	0.52±0.01	0.80±0.07	2.89±0.02

Note: EBCP is extract of black chokeberry pomace; ECP is extract of cranberry pomace; EBCL is extract of black currant leaves.

The analysis of obtained data showed that in the control sample, the intensity of hydrolytic processes in the lipid fraction of turkey MSM has more pronounced dynamics compared to the experimental ones. After one month of turkey MSM storage in the frozen state, the concentration of free fatty acids as a result of fat hydrolysis in the sample without antioxidants increased by 7.48 times and amounted to 1.87±0.03 mg of KOH. In experimental samples with a concentration of plant extracts of 0.2%, this indicator ranged from 1.65 to 0.35 mg of KOH. It was shown that addition of black chokeberry or cranberry pomace extracts slowed down the hydrolytic changes in sample fats by 81.20 and 76.47%, respectively. This is explained by the high concentration of phenolic substances contained in high amounts in the peel of the berries (Gramza-Michałowska et al., 2019; Sidor et al., 2019; Stabnikova et al., 2021).

Until the end of the storage period, the observed trend remained. Slowing down of hydrolytic processes in the fat of turkey MSM at the beginning led to inhibition of the formation of free fatty acids during the entire experimental period. At the end of the experiment, the concentration of free fatty acids in the control was the highest and amounted to 3.81±0.02 mg KOH, which is by 131.83% higher than in the EBCL0.2 sample, 4.76 times higher than in the ECP0.2 sample, and 7.33 times higher than in sample EBCP0.2. The lowest effectiveness of the antioxidant preparation EBCL is explained by the lower content of biologically active phenols (D'Urso et al., 2020).

Table 3 presents the results of the study of the acid value dynamics during storage of turkey MSM without plant antioxidants and with plant extracts added to a content of 0.3%.

Table 3

Dynamics of the acid value of turkey MSM with 03 % of plant extracts during the storage, mg KOH

Storage time, weeks	Control	EBCP0.3	ECP0.3	EBCL0.3
0	0.25±0.07	0.25±0.11	0.25±0.11	0.25±0.03
1	0.41±0.07	0.26±0.11	0.27±0.01	0.38±0.03
2	0.61±0.03	0.31±0.11	0.32±0.13	0.47±0.17
3	0.98±0.37	0.32±0.11	0.33±0.03	0.66±0.07
4	1.87±0.03	0.33±0.03	0.40±0.11	0.93±0.07
5	2.07±0.016	0.36±0,07	0.66±0.27	1.27±0.03
6	2.31±0.007	0.38±0.01	0.73±0.13	1.68±0.11
7	2.31±0.07	0.40±0.01	0.74±0.03	1.87±0.07
8	3.43±0.17	0.46±0.01	0.76±0.07	2.24±0.18
9	3.81±0.16	0.50±0.01	0.78±0.13	2.51±0.17

Note: EBCP is extract of black chokeberry pomace; ECP is extract of cranberry pomace; EBCL is extract of black currant leaves.

The hydrolytic degradation of MSM turkey fat increased over time. However, plant extracts inhibited the process of splitting fatty acids from triglycerides. An increase in concentration led to a more intense inhibition of fat hydrolysis, but the effectiveness of antioxidant drugs was different.

At the end of the storage period, the concentration of the experimental samples ranged from 2.51±0.17 to 0.50±0.01 mg of KOH. The most effective antioxidant at a concentration of 0.3% was black chokeberry extract: the intensity of fat hydrolysis in the EBCK0.3 sample was 0.50±0.01 mg of KOH, which slowed down the first stage of lipid oxidation of turkey MSM by 7.62 times. However, the difference between the effectiveness of black chokeberry extract added to turkey MSM to the content of 0.2% and 0.3% is practically absent. The situation with other antioxidants was similar.

Table 4 presents the results of the peroxide value dynamics during the storage of turkey MSM with plant extracts added to a content of 0.2%.

Table 4

Dynamics of the peroxide value of turkey MSM with 0.2% of plant extracts during the storage, J_2 %

Storage time, weeks	Control	EBCP0.2	ECP0.2	EBCL0.2
0	0.015±0.001	0.015±0.001	0.014±0.001	0.015±0.001
1	0.017±0.010	0.015±0.001	0.017±0.007	0.016±0.001
2	0.029±0.003	0.027±0.001	0.019±0.070	0.019±0.030
3	0.300±0.070	0.039±0.001	0.022±0.001	0.022±0.010
4	0.039±0.001	0.039±0.001	0.023±0.003	0.044±0.010
5	0.063±0.005	0.040±0.001	0.036±0.001	0.061±0.017
6	0.082±0.001	0.043±0.003	0.048±0.001	0.076±0.007
7	0.092±0.030	0.055±0.001	0.050±0.040	0.081±0.030
8	0.097±0.001	0.059±0.003	0.510±0.001	0.086±0.010
9	0.103±0.030	0.060±0.001	0.057±0.001	0.090±0.001

Note: EBCP is extract of black chokeberry pomace; ECP is extract of cranberry pomace; EBCL is extract of black currant leaves.

During the storage of turkey MSM, deep processes of lipid oxidation occur, which is confirmed by a gradual increase in the peroxidation number. Lipid oxidation is a free radical chain reaction that proceeds through the general stages of initiation, propagation, and termination (Kalogianni et al., 2020). However, many secondary and tertiary products formed by free radical reactions are also reactive and covalently react with surrounding components, enhancing the effects of lipid oxidation (Zamora et al., 2016). This leads to the accumulation of peroxide compounds and the growth of peroxide value. Thus, in the control sample without antioxidants, during the storage period, peroxide value increased intensively and at the end of the experimental period reached 0.103±0.030 J_2 %, which is 12.62–44.66 % higher compared to the experimental samples. The addition of black chokeberry and cranberry extracts at a content of 0.2% contributed to the reduction of peroxide value after two months of turkey MSM storage to 0.057–0.060 J_2 %, which almost halved the synthesis of peroxides in the product.

Table 5 presents the results of the peroxide value dynamics during the storage of turkey MSM with plant extracts added to a content of 0.3 %.

Table 5

Dynamics of the peroxide value of turkey MSM with 0.3% of plant extracts during the storage, J_2 %

Storage time, week	Control	EBCP0.3	ECP0.3	EBCL0.3
0	0.015±0.001	0.015±0.00	0.015±0.001	0.015±0.001
1	0.017±0.010	0.015±0.007	0.017±0.001	0.017±0.010
2	0.029±0.003	0.026±0.001	0.020±0.010	0.020±0.010
3	0.300±0.070	0.026±0.003	0.024±0.003	0.023±0.003
4	0.039±0.001	0.030±0.001	0.026±0.001	0.030±0.010
5	0.063±0.005	0.038±0.001	0.033±0.001	0.046±0.070
6	0.082±0.001	0.039±0,01	0.041±0.001	0.059±0.001
7	0.092±0.030	0.049±0,01	0.048±0.030	0.061±0.001
8	0.097±0.001	0.050±0,001	0.054±0.010	0.071±0.010
9	0.103±0.030	0.054±0.010	0.057±0.001	0.083±0.003

Note: EBCP is extract of black chokeberry pomace; ECP is extract of cranberry pomace; EBCL is extract of black currant leaves.

The most effective antioxidant at a content of 0.3% was black chokeberry extract. The content of peroxidation products of turkey MSM lipids at the end of storage was 0.054±0.010 J_2 %, which is by 47.57% lower compared to the control. Cranberry pomace extract at a content 0.3% had practically the same effectiveness.

The peroxide value in sample ECP0.3 after 9 weeks of MSM storage was 0.057±0.001 J_2%, which is by 44.66% lower than in the control sample.

This effect is explained by the presence of flavonoids in black chokeberry and cranberry pomace extracts. It is known that the high content of flavonoids has a powerful antioxidant effect in vitro (North et al., 2019). Flavonoids are able to absorb a wide range of active forms of oxygen, active forms of nitrogen and chlorine, such as superoxide, hydroxyl and peroxyl radicals. Unlike berry extracts, blackcurrant leaves extract contains a low concentration of flavonoids, mainly gallic acid, quercetin glycoside, and kaempferol glycoside (Nowak et al., 2016), which explains its weak antioxidant effect.

The thiobarbituric acid reactive substances value is one of the most commonly used parameters to detect lipid oxidation in meat and meat products (Šojić et al., 2019). Thiobarbituric acid reactive substances values at the end of storage of turkey MSM added with different amounts plant extracts are shown in Figure 2.

The effect of different plant extracts on the content of thiobarbituric acid reactive substances in turkey MSM were statistically significant ($p<0.05$). Accumulation of malonaldehyde, which is formed as a result of peroxide degradation, occurred intensively in turkey MSM without the addition of antioxidants. At the end of the storage period, the content of thiobarbituric acid reactive substances in this sample was 0.94±0.18 MA mg/kg. In experimental samples with plant extracts, the level of secondary lipid oxidation products was significantly lower. It was established that the most effective antioxidants were black chokeberry extract and cranberry extract.The content of thiobarbituric acid reactive substances in turkey MSM with these extracts at the end of the storage period was 0.57-0.61 MA mg/kg, which is 35.10–39.36% lower compared to the control sample. At the same time, the concentration of antioxidants in the range if 0.2–0.3 % practically did not affect the final result.

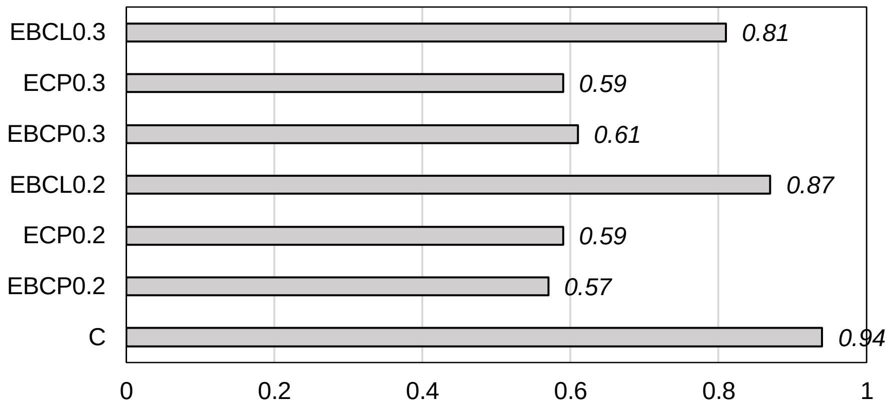


Figure 2. The content of thiobarbituric acid reactive substances in turkey MSM with plant extracts, MA mg/kg: EBCP is extract of black chokeberry pomace; ECP is extract of cranberry pomace; EBCL is extract of black currant leaves; C is control without plant extracts

It is known that the presence of proanthocyanins in black chokeberry and cranberry berries inhibits the formation of secondary lipid oxidation products (Denev et al., 2019). The concentration of substances reacting with thiobarbituric acid in samples with blackcurrant leaves extract was 0.81-0.87 MA mg/kg, which is 7.45–13.83% lower than in the control. This extract had a lower efficiency compared to other drugs, which is confirmed by (Ziobroń et al., 2021).

Conclusions

1. It has been confirmed that the turkey MSM of Ukrainian production meets the regulatory requirements in terms of chemical composition. However, the relatively high content of protein, 14.22±0.97 %, and fat, 17.3±0.64 %, increases the risk of oxidative deterioration of turkey MSM during the sale and frozen storage.
2. It was shown that addition of plant extracts to turkey MSM decreased its oxidative deterioration during the frozen storage.
3. Addition of the extracts from black chokeberry or cranberry pomace slowed down the hydrolytic changes in fats by 81.20 and 76.47%, respectively, which may be explained by the high content of phenolic substances contained in the skin of the berries.
4. During the frozen storage of turkey MSM, deep processes of lipid oxidation occur, which has been confirmed by a gradual increase of the peroxide value. The addition of black chokeberry and cranberry extracts in amount of 0.2% to raw materials contributed to the reduction of peroxide value after two months of storage of turkey MSM to 0.057–0.060 J_2 %, which almost halved the formation of peroxides in the control.
5. It was shown that the level of secondary lipid oxidation products was significantly lower in experimental samples with plant extracts. The most effective antioxidants were black chokeberry and cranberry pomace extracts. The content of thiobarbituric acid reactive substances in turkey MSM with plant extracts at the end of the storage period was 0.57–0.61 MA mg/kg, which was by 35.10–39.36% lower compared to the control sample.

References

Al-Ghayat S. M., Shaheen H. M. (2020), Quality assessment of emulsion type poultry meat products, *Suez Canal Veterinary Medical Journal*, 2(1), pp. 129-141, DOI: 10.21608/scvmj.2020.29255.1008

Bozhko, N. V., Tischenko V. I., Pasichnyi V. M. (2019a). Quality assessment of meatcontaining semi-finished minced products with duck meat. *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Food Technologies*, 21(92), pp. 8-13, DOI: 10.32718/nvlvet-f9202

Bozhko N., Tishchenko V., Pasichnyi V., Svyatnenko R. (2019b), Effectiveness of natural plant extracts in the technology of combined meatcontaining breads, *Ukrainian Food Journal*, 8(3), pp. 522-532, DOI: 10.24263/2304-974X-2019-8-3-9

Bozhko N., Pasichnyi V., Marynin A., Tischenko V., Strashynskyi I., Kyselov O. (2020), The efficiency of stabilizing the oxidative spoilage of meat-containing products with a balanced fat-acid composition, *Eastern-European Journal of Enterprise Technologies*, 3(11), pp. 38-45, DOI: 10.15587/1729-4061.2020.205201

Denev P., Číž M., Kratchanova M., Blazheva D. (2019), Black chokeberry (*Aronia melanocarpa*) polyphenols reveal different antioxidant, antimicrobial and neutrophil-modulating activities, *Food Chemistry*, 284, pp. 108-117, DOI: 10.1016/j.foodchem.2019.01.108

D'Urso G., Montoro P., Piacente S. (2020). Detection and comparison of phenolic compounds in different extracts of black currant leaves by liquid chromatography coupled with high-resolution ESI-LTQ-Orbitrap MS and high-sensitivity ESI-Qtrap MS. *Journal of Pharmaceutical and Biomedical Analysis*, 179, pp. 112926, DOI: 10.1016/j.jpba.2019.112926

Estévez M. (2021), Critical overview of the use of plant antioxidants in the meat industry: Opportunities, innovative applications andfuture perspectives, *Meat Science*, 181, pp. 108610, DOI: 10.1016/j.meatsci.2021.108610

Gramza-Michałowska A., Bueschke M., Kulczyński B., Gliszczyńska-Świgło A., Kmiecik D., Bilska A., Jędrusek-Golińska A. (2019), Phenolic compounds and multivariate analysis of antiradical properties of red fruits. *Journal of Food Measurement and Characterization*, 13, pp. 1739-1747, DOI: 10.1007/s11694-019-00091-x

Huang X., Ahn D. U. (2019), Lipid oxidation and its implications to meat quality and human health. *Food Science and Biotechnology*, 28(5), pp. 1275, DOI: 10.1007/s10068-019-00631-7

Ivanov V., Shevchenko O., Marynin A., Stabnikov V., Gubenia O., Stabnikova O., Shevchenko A., Gavva O., Saliuk A. Trends and expected benefits of the breaking edge food technologies in 2021–2030, *Ukrainian Food Journal*, 2021, 10(1), pp. 7-36, DOI: 10.24263/2304-974X-2021-10-1-3

Kalogianni A. I., Lazou T., Bossis I., Gelasakis A. I. (2020), Natural phenolic compounds for the control of oxidation, bacterial spoilage, and foodborne pathogens in meat, *Foods*, 9(6), pp. 794, DOI: 10.3390/foods9060794

Komrska P., Tremlová B., Štarha P., Simeonovová J., Randulová Z. (2011), A comparison of histological and chemical analysis in mechanically separated meat, *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, *59*(1), pp. 145-152, DOI: 10.11118/actaun201159010145

Łaszkiewicz B., Szymański P., Zielińska D., Kołożyn-Krajewska D. (2021), Application of *Lactiplantibacillus plantarum* SCH1 for the bioconservation of cooked sausage made from mechanically separated poultry meat, *Applied Sciences*, 11(4), pp. 1576, DOI: 10.3390/app11041576

Massingue A. A., de AlmeidaTorres Filho R., Fontes, P. R., Ramos A. D. L. S., Fontes E. A. F., Perez J. R. O., Ramos E. M. (2018), Effect of mechanically deboned poultry meat content on technological properties and sensory characteristics of lamb and mutton sausages, *Asian-Australasian Journal of Animal Sciences*, 31(4), 576, DOI: 10.5713/ajas.17.0471

Munekata P. E. S., Rocchetti G., Pateiro M., Lucini L.; Domínguez R., Lorenzo J. M. (2020), Addition of plant extracts to meat and meatproducts to extend shelf-life and health-promoting attributes: An overview, *Current Opininion Food Science*, 31, pp. 81–87, DOI: 10.1016/j.cofs.2020.03.003

North M. K., Dalle Zotte A., Hoffman L. C. (2019), The use of dietary flavonoids in meat production: A review, *Animal Feed Science and Technology*, 257, pp. 114291, DOI: 10.1016/j.anifeedsci.2019.114291

Nowak A., Czyzowska A., Efenberger M., Krala L. (2016), Polyphenolic extracts of cherry (*Prunus cerasus* L.) and blackcurrant (*Ribes nigrum* L.) leaves as natural preservatives in meat products, *Food Microbiology*, 59, pp. 142-149, DOI: 10.1016/j.fm.2016.06.004

Pateiro M., Munekata P. E. S., Sant'Ana A. S., Domínguez R., Rodríguez-Lázaro D., Lorenzo J. M. (2021), Application of essential oils asantimicrobial agents against spoilage and pathogenic microorganisms in meat products, *International Journal of Food Microbiology*, 337, pp. 108966, DOI: 10.1016/j.ijfoodmicro.2020.108966

Pérez-Palacios T., Estévez M. (2020), Analysis of lipids and lipid oxidation products. In: *Meat Quality Analysis*, Elsevier, pp. 217-239, DOI: 10.1016/B978-0-12-819233-7.00013-6

Püssa T., Raudsepp P., Toomik P., Pällin R., Mäeorg U., Kuusik S., Rei M. (2009), A study of oxidation products of free polyunsaturated fatty acids in mechanically deboned meat, *Journal of Food Composition and Analysis*, 22(4), pp. 307-314, DOI: 10.1016/j.jfca.2009.01.014

Ribeiro L. B., Bankuti F. I., da Silva M. U., Ribeiro P. M., Silva J. M., Sato J., Vasconcellos R. S. (2019), Oxidative stability and nutritional quality of poultry by-product meal: An approach from the raw material to the finished product, *Animal Feed Science and Technology*, 255, pp. 114226, DOI: 10.1016/j.anifeedsci.2019.114226

Sidor A., Gramza-Michałowska A. (2019), Black chokeberry *Aronia melanocarpa* L. - A qualitative composition, phenolic profile and antioxidant potential, *Molecules*, 24(20), pp. 3710, DOI: 10.3390/molecules24203710

Šojić B., Pavlić B., Ikonić P., Tomović V., Ikonić B., Zeković Z., Ivić M. (2019), Coriander essential oil as natural food additive improves quality and safety of cooked pork sausages with different nitrite levels, *Meat Science*, 157, pp. 107879, DOI: 10.1016/j.meatsci.2019.107879

Stabnikova O., Marinin A., Stabnikov V. (2021), Main trends in application of novel natural additives for food production, *Ukrainian Food Journal*, 10(3), pp. 524–551, DOI: 10.24263/2304-974X-2021-10-3-8

Takács K., Szerdahelyi E., Nagy A., Gelencsér É. (2021), Mechanically deboned turkey meat with improved digestibility and biological value, *Acta Alimentaria*, 50(3), pp. 322-332, DOI: 10.1556/066.2020.00307

Tasić A., Kureljušić J., Nešić K., Rokvić N., Vićentijević M., Radović M., Pisinov B. (2017), Determination of calcium content in mechanically separated meat, *IOP Conference Series: Earth and Environmental Science*, IOP Publishing, 85(1), p. 012056, DOI: 10.1088/1755-1315/85/1/012056

Tischenko V. I., Bozhko N. V., Pasichnyi V. M., Brazhenko V. V. (2019). Investigation of organoleptic and functional-technological parameters of meat breads using mechanically deboned poultry meat, *Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies. Series: Food Technologies*, 21(91), pp. 3-8, DOI: 10.32718/nvlvet-f9101

Trindade M. A., Nunes T. P., Contreras-Castillo C. J., Felício P. E. D. (2008), Oxidative and microbiological stability of mechanically separated hen meat pre blended with antioxidants during frozen storage, *Food Science and Technology*, 28, pp. 160-168, DOI: 10.1590/S0101-20612008000100023

Wu H., Richards M. P., Undeland I. (2022), Lipid oxidation and antioxidant delivery systems in muscle food, *Comprehensive Reviews in Food Science and Food Safety*, 21(2), pp. 1275-1299, DOI: 10.1111/1541-4337.12890

Yin J., Zhang W., Richards M. P. (2017), Attributes of lipid oxidation due to bovine myoglobin, hemoglobin and hemolysates. *Food Chemistry*, 234, pp. 230-235, DOI: 10.1016/j.foodchem.2017.04.182

Zamora R., Hidalgo F. J. (2016), The triple defensive barrier of phenolic compounds against the lipid oxidation-induced damage in food products, *Trends in Food Science & Technology*, 54, pp. 165-174, DOI: 10.1016/j.tifs.2016.06.006

Ziobroń M., Kopeć A., Skoczylas J., Dziadek K., Zawistowski J. (2021), Basic chemical composition and concentration of selected bioactive compounds in leaves of black, red and white currant, *Applied Sciences*, 11(16), pp. 7638, DOI: 10.3390/app11167638

Effective frequency of displaying the communication message to consumers of beer brand in digital media

Kateryna Semenenko[1], Larysa Kapinus[1], Iryna Boiko[1], Volodymyr Kucherenko[2], Nataliia Skryhun[1]

1 – National University of Food Technologies, Kyiv, Ukraine
2 – Ukrainian Corporation for Viticulture and Wine Industry "Ukrvinprom"

Keywords:

Beer
Brand
Marketing
online-Advertisement
Media.

Article history:

Received 23.06.2022
Received in revised form 11.12.2022
Accepted 30.12.2022

Corresponding author:

Iryna Boiko
E-mail: boikoia@nuft.edu.ua

DOI: 10.24263/2304-974X-2022-11-4-11

Abstract

Introduction. The research is devoted to the determination of effective display frequency of advertised communication messages to consumers in representative samples of the brewing industry to optimize the media budget.

Materials and methods. The study is based on the scientific research of scientists on the development of beer market and digital economy, theories of advertisement message frequency, marketing research of brewing enterprises and their brands to determine the minimum range of effectiveness of advertised messages to beer consumers.

Results and discussions. The frequency of displaying the communication message determines not only the effectiveness of appeals to the consumer, but also spending on media budget, however, currently there is no single point of view to this problem in scientific research. Both an insufficient amount of appeals and an excessive frequency lead to insufficient budget using. Effective frequency of the message influences not only on consumer's purchasing behaviour and indicators of brand's health but also allows to optimize media budget. Certainly, most media planners use the effective frequency strategy «three plus».

In order to determine the frequency of communication with consumers for instruments of online-advancement of beer the modified Matrix of Ostrow is given. The blocks of factors of influence on beer promotion on the consumer market are improved, they are «Market factors», «Factors of quality of advertisement message», «General media factors». «Online media factors» block is added, where such indexes as description of placement the resources, use of social media, use of video formats, use of non-standard displays and formats, coverage of media channel, type of placement, accordance to general content of campaign are considered.

Adaptation of the improved matrix took place on the example of the most beer brands of the market, for this reason the effective frequency of repetition of communication message and comparing to actual is carried out, that allowed to group brands into 4 groups from position of strategy of further charges to placement of advertised messages in the Internet.

Conclusions. For planning the frequency of communication messages it is suggested to use the adapted matrix for determination the effective frequency communication with consumers of beer brands in order to optimize the media market.

Introduction

The analysis of the development of the brewery industry showed signs of globalisation of the beer market and its digitalization (Madsen and Wu, 2016). Part of the international beer market is the brewing industry of Ukraine, which produces more than 400 types of beer products and supplies them to 42 countries of the world (Pryimachuk et al., 2018). The transaction of many beer brands from the regional market to the global market also requires the formation of a complex of online marketing communication and product branding. Therefore, the optimization of advertising costs in digital media for the promotion of brewing products is one of the most pressing issues today.

In the modern world every producer uses the advertisement for presentation of his/ her commodity or services to the potential consumers. Allocation of charges on searching on-line-advertisement in 2020 was: Australia, $4.5 milliards, France, $3.1 milliard, Germany, $4.7 milliards, Ireland, $427 million, England, $10.8 milliards, USA, $60.9 milliards. In terms of growth, all countries have seen significant increases in the costs of digital advertising, with COVID-19 representing a small deviation in the general trend. For example, Ireland saw the digital advertising spend in the Irish market for 2019 rise by 17% to reach EUR 673 million. In France, 2018 saw digital becoming the leading medium for advertising sales (40%), compared with 27% for television (Fourberg et al, 2021).

Researches of eMarketer (Cramer - Flood, 2021) show that world charges on an advertisement in 2021 was about $491, 70 milliards, charges on digital advertisement - $146, 12 milliards. Google has about 38% of all global increase of charges on digital advertisement. Researches of eMarketer (Cramer - Flood, 2021) show that world charges on an advertisement in 2021 was about $491, 70 milliards, charges on digital advertisement - $146, 12 milliards. Google has about 38% of all global increase of charges on digital advertisement.

The excessive number of impressions sent to the user by the advertisers cause the users to get annoyed with products they are not interested in. At the same time, it causes the advertiser to waste vast amounts of money. For this reason optimization of a great amount of advertising requests to the potential consumers, many scientists and practical workers are engaged in (Chu et al., 2012; Leguina et al., 2021; Schmidt et al., 2015).

Traditionally, one of the basic instruments for media planning are coverage and frequency. Questioning of advertisement practical workers showed that coverage and frequency had come forward as major factors at the choice of mass media (Kreshel et al., 1985, Cheong et al., 2010).

The analysis of effective coverage and effective frequency shows two points of view to the same question. Effective frequency shows, how many displays are needed, that the advertisement became «effective»; effective coverage concerns amounts of people, which are exposed to influence on this level (Cannon, 1994).

Importance of frequency as one of indexes of media planning was marked by many researchers (Cannon et al., 2002; Cheong et al., 2010; Jeong et al., 2011; Makienko, 2012;). It is related foremost to psychological bases of advertisement, in particular, with memorizing, that in the conditions of strengthening of general informative clutter and changes of consumer's behaviour of the content (decline of threshold of attention, time reduction of focus on the message, clip-like thinking and perception) acquires special importance.

In order to achieve the goal of advertising, to optimize the advertising budget by determining the optimal number of effective contacts with potential customers, it is important to determine the frequency saturation of advertising (advertising saturation frequency) which determines the optimal number of repetitions of an advertising message necessary to achieve a certain level of awareness of its target audience. It is important to ensure that the message is displayed enough times for potential customers to understand it and remember it, while at the same time not annoying them with an excessive frequency of advertising, so that they do not get tired of repetitions and do not feel a negative attitude towards advertising. Thus, achieving the optimal number of effective contacts will ensure the maximum effectiveness of the advertising campaign.

Last years the internet became a basic environment for advertisers. Mass media and form of advertisement are developing quickly, and the models of consumption of media continue to change (Cheong et al., 2010), that is why efficiency of media planning and determination of frequency of communication in digital epoch grows only.

Presently there is plenty of models by means of that media planners can define optimal frequency for different media (Cheong, 2010; Leckenby and Kim, 1994; Leckenby and Hong, 1998). However, even computer-assisted models helped to decide this question (Makienko, 2012), as optimization mainly depends on the price for display and does not take into account many quality factors (Ephron, 1998).

These factors were first presented by Joseph Ostrow, he is the author of one of the methods of determination of effective frequency of communication. In particular, the matrix of Ostrow comes forward as a practical method of determination the effective frequency for advertisement message that allows to analyse 20 factors that is divided into three groups (Ostrow, 1984).

It should be noted that the list of factors and specific of their grouping in a greater measure answer the specific of off-line advancement instruments and does not take into account the features of application of instruments of on-line advancement in the Internet-environment, and also work directly with alcoholic brands (including beer) in the conditions of present legislative limitations of advertisement and communication activity of the enterprises-producers. Therefore, the aim of the research is the development of adapted under the specific of the use of instruments of on-line-advancement and of advertisement and communication work in the conditions of Dark market matrix with the aim of determination the effective frequency of communication.

Materials and methods

Materials

To achieve the goals of the research, literary sources were elaborated on the development of the beer market and the digital economy (Madsen and Wu, 2016; Pryimachuk et all, 2018; Fourberg et al, 2021; Cramer-Flood, 2021), on the relevance of the frequenc of the advertising message (Cannon, 2002; Cheong, 2010; Chu et al, 2012; Jeong 2011; Kreshel, 1985; Leguina et al, 2021; Makienko, 2012; Schmidt and Eisend, 2015), basic theories of the frequency of advertising messages (Cannon, 1994; Heath, 2012; Krugman, 1972; McDonald, 1970; Naples, 1997; Stewart, 1989).The study of the scientific researches (Aslam et al, 2021; Betancur et al 2020; Cortinas et al, 2019; Makienko, 2012; Ostrow, 1984; Watrobski et al, 2016; Yasmin et al, 2015), made it possible to modify the Ostrow matrix for determining the frequency of an advertising message CCsconsumers when promoting beer online. The subjects of the research were the brands of major beer producers, which 80% of the consumer market of Ukraine: PJSC “Carlsberg Ukraine”, which belongs to the Carlsberg Group (Denmark), PJSC «ABinBev

Ukraine» which is the part of Anheuser-Busch InBev (Belgium), PJSC «Obolon» (Ukraine), LLC «TPC «PPB») which is the part of the international holding (Ukraine, Germany, Kazakhstan). The modified matrix was tested on a representative sample of 15 beer brands that is included in the assortment portfolio of the presented largest Ukrainian beer producers.

Methods

The research carried out a literature review, used a systematic approach to determine the blocks of the modified matrix for determining the effectiveness frequency of communication on the Internet, applied methods of statistical analysis, generalization and comparison, to study the planned and actual frequency of communication for online promotion instruments of the largest beer brands of the Ukrainian market and the division of brands into groups from the standpoint of the strategy of further spending on advertising on the Internet, the obtained conclusions are based on the methods of scientific interpretation and systematization.

Results and discussion

Theoretical approach of effective frequency of communication message

The effective frequency concept suggests that for nearly all products there exists an optimal number of advertising exposures below which no or little effect is observed, and above which advertising effectiveness demonstrates diminishing return (Stewart, 1989). Conception of effective frequency planning (EFP) for a long time was the dominant paradigm of media planning. In particular, conception was set the effective level of frequency as three displays and it was marked on importance of reiteration of the message, as one coverage without reiterations will not result in sales (Naples, 1997).

Such amount of displays is related to the reason that between the revision of advertisement content and directly purchase passes set time that is why it is needed, if a consumer remembered the message near the shelf exactly in the moment of decision-making about purchase. The theory of the psychology of the learning process states that in order to remember information and move to the formation of habits, this process must be repeated several times – on average 3 times. American psychologist Herbert Simon (*Simon, 1978*) believed that a person usually remember information after about 3-5 repetitions. Although this statement is not absolutely accurate in all cases, because the number of repetitions necessary for learning and forming a habit can be different for different people and different situations, it can be useful in planning the process of learning and learning new advertising information.

According to the research of Krugman (1972) most advertisements are reminders, and the frequency of their display helps to be noticed by consumers at a critical moment. Krugman emphasized that the first impression is unique and the second impression allows you to assess the personal relevance of the advertisement. The third display is a true reminder, which is why Krugman called for more frequent display.

Well-known scientists (Heath, 2012; Krugman, 1972; McDonald, 1970; Naples, 1979), who studied the effectiveness of the frequency of advertising, recommended its repetition at least three times. They confirmed with research of the importance of repeating an advertising message for effective memorization and habit formation, and also proved that the effectiveness of advertising depends not only on its frequency of display, but also on its context, performance quality, target audience and other factors. Thus, often the emotional impact of advertising on the consumer is more significant than the simple repetition of the advertising message (Heath, 2012).

Effective «three plus» frequency strategy has been implemented by 90 percent of advertisers of the packaged goods in the United States. Even today, this rule is very popular (Makienko, 2012).

At the same time it should be noted that in the conditions of realities of modern media market on classic frequency of F=3 is not always effective. First of all, it is related to the dynamics of media space development and switching of users between different media and such phenomenon as multi-screening that substantially influences on the average rate.

These and other lacks of EFP are examined in such systems of media planning, as the «Optimal frequency planning» (OFP) of 1994 and conception of «Frequency value planning» (FVP) (Cannon et al., 1994; Cannon et al., 2002). The central idea of OFP and FVP is to weight every level of exposure in the frequency distribution with the probability that each level of advertising exposure will have impact on consumers, as demonstrated by the advertising response curve (Cheong et al., 2010).

Schmidt and Eisend (2015) studied the amount of advertisement displays that stimulate consumers to purchase. It is set that in experimental terms a consumer begins to react on an advertisement appeal approximately after ten displays. Memorizing of advertisement appeal grows and only after the 8^{th} contact with a consumer begins to level off. In addition, it was found that the effect of repeating of advertisement appeal in course of time results in reduction of emotional connection of consumer with brand and weaker memorability of advertising appeal.

In research (Pedreño-Santos et al., 2022) the connection between frequency and memorability in a radio advertisement by the study of basic signs of coverage and frequency is determined. In accordance with the results of the research the effective frequency is the range from 4 to 17 displays (where 7 is optimal average value).

In the work (Naples, 1979) there is the results of the research on obtaining a negative reaction due to the use of too many repetitions of communication message. There is even a risk that due to the high level of frequency some consumers are able to forget all advertising messages.

Zanuddin (2004) accents attention on the non-permanent display of communication message to the consumers (within the limits of purchase cycle) brings an insignificant or zero effect. Two contacts in the buying cycle are effective threshold. However three displays in the buying cycle are considered optimal. At the same time exhaustion of advertising campaigns takes place not only through superfluously high-frequency, but also from problems with the text and content. Individual researches are required to find frequency levels for each brand. Two brands that spend an equal sum on advertisement can cause different reaction depending on frequency.

In turn there are researches, that show that show that there is no special difference at frequency of messages of 1 time or 3 times. On interest and desire to purchase a commodity Advertisement creativity has the greatest influence on interest and desire to purchase the commodity (Budiawan of et al, 2017).

There are also researches that show, what factors of influence on the value of advertisement: brand image, image in advertisement, frequency of advertisement. Finally, this study found that advertising frequency influences consumers’ attitude towards advertising. In addition, this study also found that higher frequency has higher influence on consumers' attitude, which differs from the theory that higher frequency of advertising has less effect because it bores the audience (Chu et al., 2012). Leguina et al. (2021) offered methodology of determining the correct amount of advertisement displays, maximize the efficiency of enterprise's activity. Their methodology is based on hypothesis that was confirmed experimentally: the more impressions the user receives, the less probability, that he will become interested by the advertiser's products. The coefficient of cooperation that has the tendency to decrease as the number of impressions received by the user increases is given.

Planning of frequency of advertisement campaign in the Internet, unlike standard of off-line instruments (TV, external advertisement, radio, advertisement and advertisement in print publications), is more difficult process, that is related to the specific of consumer's behaviour in the Internet (in particular, by difficulty of predicting the network user's movement scenario), by the different level of penetration in different age groups and intersection of audiences of different resources, which is not always possible to accurately predict. At the same time, online advertisement campaign planning has a number of advantages that are not accessible for traditional media. For example, possibility of advertisement message adaptation under the profile of Network audience (message or accents and method of messages can differ between TV-content and by Internet-content), possibility of having a special purpose of targeting and use of social engineering technologies (translation of differentiated messages depending on social demographic and psychographic characteristics of the audience). Similar technologies have been successfully used in recent years by political technologies to deliver differentiated communication messages to representatives of specific target audiences.

Improvement of matrix of Ostrow for the use taking into account the specific of work with instruments of online-advancement

Among the existent methods of determination the effective frequency of communication the matrix of Ostrow (Joseph W. Ostrow) is often used that allows to analyse 20 factors which are divided into three groups (Ostrow, 1984*)*:

–market factors (market reasons, such as popularity and position of brand at the market, degree of loyalty to the brand, frequency of use/consumption of the product, part of voice in clutter, key features of target audience);

–factors of quality of advertisement messages (indexes of quality of marketing message, such as complication and unicity of the message, history of communication, type of communication, variability, attrition and duration of the message);

–media factors (indexes that characterize competitive activity in advertisement, degree of audience attention to the advertisement and characteristics of media placement of the video) (Watrobski et al, 2016).

The method makes it possible to define the influence of factors according to the specified three groups on the effectiveness of return from an advertisement, to digitize them and as a result to define the minimum threshold of effective frequency for marketing communication.

The analysis of author's factors led to the conclusion that separate factors of matrix are absolutely irrelevant for application in the analysis of brands that belong to the commodities whose advertising is limited by the effect of Law of Ukraine «About an advertisement». In addition, some of the factors are impossible to use taking into account the specifics of work with the instruments of on-line-advancement (Kapinus et al, 2020).

With the aim of achievement the most effectiveness from the point of view of the theoretical and practical providing of media planning process, it would be advisable to adjust the list and formulations of factors and blocks that influence on the determination of effective frequency of communication exactly for the instruments of on-line-advancement of beer brands (Skrygun et al, 2016).

In particular, in research it is suggested to withdraw the «Market factors» of evaluation of factors of duration cycle of purchase and frequency of consumption from the block, as not relevant for the typical commodities of FMCG group, which include beverages in the Beer category. As a replacement it is proposed to introduce an indicator that characterizes drinkability, id est the level of lightness of taste profile and can indirectly indicate the frequency of consumption from the point of view of general tendencies of beer consumption at the global market and at the market of Ukraine in particular (Betancur et al, 2020).

The similar point of view is held by the researcher (Makienko, 2012) who noted that factors of duration cycle of purchase and frequency of consumption were not relevant, since each consumer make purchase decisions at different times, accordingly at the market always present customers.

The factor of age (in particular, children’s) is proposed to be removed as it contradicts the norms of the Law of Ukraine (About State Regulation). Instead, we propose to include polar characteristics of target audience: traditionalists-innovators that largely represent distribution not only on the profile of beer consumption of one or another sort/of brand but also characterize a potential level of Network penetration.

From the block «Factors of quality of advertisement message» to withdraw the factor of «duration of advertisement blocks», because this indicator is such, that it does not sufficiently characterize the specificity of the instruments of on-line-advancement. There are standard timings for all types of instruments of on-line-advancement the use of which can at least partially guarantee the achievement of message r to the target audience and increase probability of passage through the communication barriers of the Internet (communication, filters, lack of audio and others like that) (Aslam et al., 2021).

Block consider «Mediafactors» consider it appropriate to rename into «General media factors» (Betancur et al., 2020), because it would be methodically logical to eliminate the following factors from the block: compliance of brand content with the characteristics of medias and description of media channel coverage, since in general only the Internet is consider; type of placement - through placement in one of media and through the presence of more unfolded parameters of placement in the new block of «Online media factors». It is proposed to replace the characteristics of the evaluation of the number of channels with 1-2 channels and 3+ with more progressive and corresponding to the latest media planning trends - Monochannel / Polychannel (360º) (Cortinas et al., 2019).

Considering that online promotion has some features that are determined by specific indicators (Semenenko et al, 2019; Yasmin et al, 2015), it is advisable to add “Online media factors” the following blocks:

– characteristics of placement resources
– use of social media;
– use of banned advertising;
– use of video formats;
– use of non-standard manifestations and formats;
– coverage of the media channel;

– type of placement;
– compliance with the general content of the campaign.

It was considered that the evaluation of factors of additional block will give an opportunity to conduct the quantitative subject digital analysis of the frequency of on-line-advancement instruments, that, in turn, will give an opportunity to get reasonable conclusions and form recommendations in relation to optimization effectiveness of media planning process and, as a result, of media budget.

Thus, the main indicators of adapted matrix for determining the effectiveness of frequency of communication message for the instrument of online-advancement of beer brands can be interpreted as follows (basic indicators are close to the interpretations *(Ostrow, 1984*) and added by authors in this edition. The general structure of the adapted matrix for determining the effective communication frequency for instruments of online-advancement of alcoholic / beer brands is shown in Figure 1.

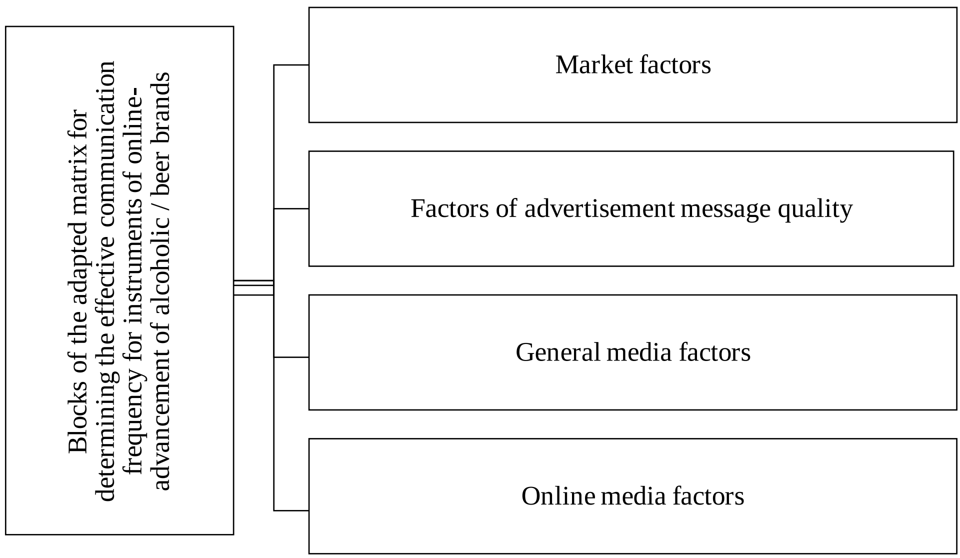


Figure 1. Blocks of the adapted matrix for determining the effective communication frequency for instruments of online-advancement of alcoholic / beer brands

Detailed comment on the mechanics of the estimation factors in the sections of blocks are given in Table 1.

Table 1

Adapted matrix of determination of effective frequency of communication for instruments of on-line-advancement of alcoholic / beer brands

№	Decrease in frequency	Frequency correction				Increase in frequency
Market factors						
1	Famous brand	- 2	- 1	1	2	New brand
2	High market share	- 2	- 1	1	2	Low market share
3	High level of loyalty to the brand	- 2	- 1	1	2	Low level of loyalty to the brand
4	Drinkability profile of taste / frequent consumption	- 2	- 1	1	2	undrinkable profile of taste/ not frequent consumption
5	Low share of voice is planned	- 2	- 1	1	2	High share of voice is planned
6	Target audience – innovators	- 2	- 1	1	2	Target audience - traditionalists
Factors of advertisement message quality						
7	Low complexity of advertising message	- 2	- 1	1	2	High complexity of advertising message
8	High uniqueness, message novelty	- 2	- 1	1	2	Low uniqueness, message novelty
9	Old message	- 2	- 1	1	2	New message
10	Product communication	- 2	- 1	1	2	Image communication
11	Low variation of the message	- 2	- 1	1	2	High variation of the message
12	High wear and tear of the message	- 2	- 1	1	2	Low wear and tear of the message
General media factors						
13	Low activity of the competitors (small clutter)	- 2	- 1	1	2	High activity of the competitors (high clutter)
14	High level of audience's attention	- 2	- 1	1	2	Low level of audience's attention
15	Limited amount of media channels	- 2	- 1	1	2	Using of increased number of media channels
Online media factors						
16	Determination of priority (thematic) resources for content placement	- 2	- 1	1	2	Packed placement without specifying the user profile
17	Promotion in social networks	- 2	- 1	1	2	Lack of support of social networks
18	Work with banner advertisement	- 2	- 1	1	2	No banner ads
19	Work with video formats (YouTube)	- 2	- 1	1	2	Lack of support for video formats (YouTube)
20	Non-standard manifestations and formats	- 2	- 1	1	2	Lack of non-standard manifestations and formats
21	Placement on the resources that have high-frequency coverage	- 2	- 1	1	2	Placement on the resources that have low-frequency coverage
22	Constant presence of content	- 2	- 1	1	2	«Seasonal» work or between TV flights
23	Connection with the content of other channels of communication	- 2	- 1	1	2	Lack of connection with the content of other channels of communication

Source: given by authors

Use of adapted matrix of Ostrow on the example of most brands of beer of Ukraine

During 2020 in Internet-media such brands of beer (most from the point of view of budget advancements in Network) were present:

- TM «Lvivske» (PJSC «Carlsberg Ukraine»);
- TM «Chernihivske» (PJSC «ABinBev Ukraine»);
- TM «Obolon» (PJSC «Obolon»);
- TM «Zakarpatske» (LLC «TPC «PPB»);
- TM «Svizhyi rozlyv» (LLC «TPC «PPB»);
- TM «Baltyka» (PJSC «Carlsberg Ukraine»);
- TM «Bilyi vedmid» (PJSC «ABinBev Ukraine»);
- TM «STELLA ARTOIS» (PJSC «ABinBev Ukraine»);
- TM «TUBORG» (PJSC «Carlsberg Ukraine»);
- TM «HIKE» (PJSC «Obolon»);
- TM «CORONA» (PJSC «ABinBev Ukraine»);
- TM «KRUSOVICE» (LLC «TPC «PPB»);
- TM «KRONENBOURG 1664» (PJSC «Carlsberg Ukraine»);
- TM «HOEGAARDEN» (PJSC«ABinBev Ukraine»);
- TM «SETH & RILEYS GARAGE» (PJSC «Carlsberg Ukraine»).

The above-mentioned trademarks used the different variants of communication mix of instruments of on-line-advancement within the framework of brand strategy. Frequency on which the brands worked with communication messages, in accordance with the reports of independent media audit is given in Table 2.

As it is evidently from the results of audit the frequency of communication for most brands of beer market, greater part of brands worked on midfrequency - 3. Rejection was observed in the vast majority at actually less frequency of placing. For frequency communication planning most brands of the market on the indexes of the level of beer media budget of instruments of advancement will apply the adapted matrix for determination of effective frequency of communications for instruments of on-line-advancement. The consolidated information is generalized by authors in Table 3.

For better visualization of given results, a comparison of actual and estimated communication frequency for instruments of online advancement is grouped in Table 4.

For conditional optimum it is possible to take frequency 3 that is considered as average frequency from the point of view of achievement of desirable changes in purchasing behaviour, aims of brand health charges of media budget which is supported by the research (Krugman 1972; McDonald, 1970; Naples, 1979; Zanuddin, 2004). Exactly this frequency is elected by most companies as such from that correlations of cost-effectiveness (8 from 15 brands by results of the audit of media indexes of advertisement campaigns in the Internet in 2020 p) expect optimally.

Use of offered by authors adapted matrix of determination of effective frequency of communication for instruments of online-advancement allows to correct this index taking into account influence of environment (market factors, factors of quality of advertisement message, general media factors, on-line media factors). For conditional maximum accept frequency 5 as such that is maximally recommended for work in any of media. Exceeding through this limitation can lead to the formation of negative perception of the brand in the consumer due to the increase in the comfortable number of branded paraphernalia and inventory in the point of view of one specific representative of target audience. In addition, working at the frequency of 5+ actually means the irrational use of media budget, as it turns a potentially desirable contact with content into noise and increase the possibility of passing through advertising clutter which are supported by the research (Leguina et al, 2021; Naples, 1979).

In accordance with authorial methodology of the got results from the position of strategy of further charges to placing in the Internet can be distinguished 4 groups of brands (Figure 3):

- «Group Optimum» –calculative efficiency coincides with actual; deviation is equal /0/.
- «Group Expenses» – calculative efficiency is less than than actual; deviation is more or equal the value of /-1/;
- «Group Expenses +» – calculative efficiency is more than actual; deviation is in the range of /1-2/;
- «Group Expenses 2+» – calculative efficiency is significantly larger than actual; deviation is more than /2/.

Table 2

Planned and actual frequency of communication for instruments of online-advancement of most beer brands of Ukrainian market on the index of media budget level, 2020

Brand / Trade mark	Frequency		Deviation
	Planned	Actual	
TM «Lvivske» (PJSC «Carlsberg Ukraine»)	4	5	1
TM «Chernihivske» (PJSC «ABinBev Ukraine»)	5	4	-1
TM «Obolon» (PJSC «Obolon»)	3	3	0
TM «Zakarpatske» (LLC «TPC «PPB»)	3	3	0
TM «Svizhyi rozlyv» (LLC «TPC «PPB»)	3	2	-1
TM «Baltyka» (PJSC «Carlsberg Ukraine»)	2	3	1
TM «Bilyi vedmid» (PJSC «ABinBev Ukraine»)	3	2	-1
TM «STELLA ARTOIS» (PJSC «ABinBev Ukraine»)	3	3	0
TM «TUBORG» (PJSC «Carlsberg Ukraine»)	3	3	0
TM «HIKE» (PJSC «Obolon»)	4	3	-1
TM «CORONA» (PJSC «ABinBev Ukraine»)	3	3	0
TM «KRUSOVICE» (LLC «TPC «PPB»)	3	2	-1
TM «KRONENBOURG 1664» (PJSC «Carlsberg Ukraine»)	3	3	0
TM «HOEGAARDEN» (PJSC«ABinBev Ukraine»)	3	2	-1
TM «SETH & RILEYS GARAGE» (PJSC «Carlsberg Ukraine»)	4	4	0

Source: *summarised by authors according to the data of analytical agency Kwendi*

Table 3

Estimations of effective frequency of displays of communication messages through the instruments of online-advancement of brands by the adapted methodology

Factor number	Frequency correction														
	«Lvivske»	«Chernihivske»	«Obolon»	«Zakarpatske»	«Svizhyi rozlyv»	«Baltyka»	«Bilyi vedmid»	«STELLA ARTOIS»	«TUBORG»	«HIKE»	«CORONA»	«KRUSOVICE»	«KRONENBOURG1664»	TM «HOEGAARDEN»	«SETH & RILEYS
Market factors															
1	-2	-2	-2	-2	-2	-1	-1	-2	-2	-1	-1	-2	-2	-1	-2
2	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	-1	-1	-1	-1	-2
3	-2	-2	-2	-2	-2	-2	-2	-1	-1	-1	-1	-1	-1	-1	-2
4	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	1	1	1	1	-2
5	2	1	1	2	1	1	2	1	1	1	1	1	2	1	1
6	2	2	2	2	2	2	1	-2	-2	-2	-2	-2	-2	-2	-2
Factors of advertisement message quality															
7	-1	1	1	-1	1	1	-1	2	1	-1	1	2	2	2	1
8	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
9	2	-1	-2	2	-1	-2	2	-1	-2	2	-1	-2	2	-1	2
10	2	1	1	3	1	1	2	1	1	2	1	1	2	1	1
11	2	1	1	1	1	1	2	1	1	2	1	1	2	1	1
12	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
General media factors															
13	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	2	-2	1	2	-2	1	2	-2	1	2	-2	1	2	-2
Online media factors															
16	-1	1	1	-1	1	1	-1	1	1	-1	1	1	-1	1	1
17	-1	1	-1	-1	1	-1	-1	2	2	-1	1	-1	-1	1	-1
18	-2	-2	-1	-2	-2	-1	-2	-2	-1	-2	-2	-1	-2	-2	-1
19	-1	-2	1	-1	-2	1	-1	-2	1	-1	-2	1	-1	-2	1
20	-1	1	1	-1	1	1	-1	1	1	1	1	1	-1	1	1
21	1	2	1	1	2	1	1	2	1	1	2	1	1	2	1
22	2	-2	2	2	-2	2	2	-2	2	2	-2	2	2	-2	2
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	4	3	3	4	3	4	4	3	4	4	5	5	8	6	3

Source: created by authors

Table 4

Comparison of actual and calculation effective of frequency of communication for instruments of on-line-advancement

Brand / Trade mark	Actual frequency	Calculated effective frequency	Deviation	Group
TM «Lvivske» (PJSC «Carlsberg Ukraine»)	5	4	-1	Costs-
TM «Chernihivske» (PJSC «ABinBev Ukraine»)	4	3	-1	Costs-
TM «Obolon» (PJSC «Obolon»)	3	3	0	Optimum
TM «Zakarpatske» (LLC «TPC «PPB»)	3	4	1	Costs+
TM «Svizhyi rozlyv» (LLC «TPC «PPB»)	2	3	1	Costs+
TM «Baltyka» (PJSC «Carlsberg Ukraine»)	3	4	1	Costs+
TM «Bilyi vedmid» (PJSC «ABinBev Ukraine»)	2	4	2	Costs+
TM «STELLA ARTOIS» (PJSC «ABinBev Ukraine»)	3	3	0	Optimum
TM «TUBORG» (PJSC «Carlsberg Ukraine»)	3	4	1	Costs+
TM «HIKE» (PJSC «Obolon»)	3	4	1	Costs+
TM «CORONA» (PJSC «ABinBev Ukraine»)	3	5	2	Costs+
TM «KRUSOVICE» (LLC «TPC «PPB»)	2	5	3	Costs 2+
TM «KRONENBOURG 1664» (PJSC «Carlsberg Ukraine»)	3	8	5	Costs 2+
TM «HOEGAARDEN» (PJSC«ABinBev Ukraine»)	2	6	4	Costs 2+
TM «SETH & RILEYS GARAGE» (PJSC «Carlsberg Ukraine»)	4	3	-1	Costs-

Sourse: *created by authors*

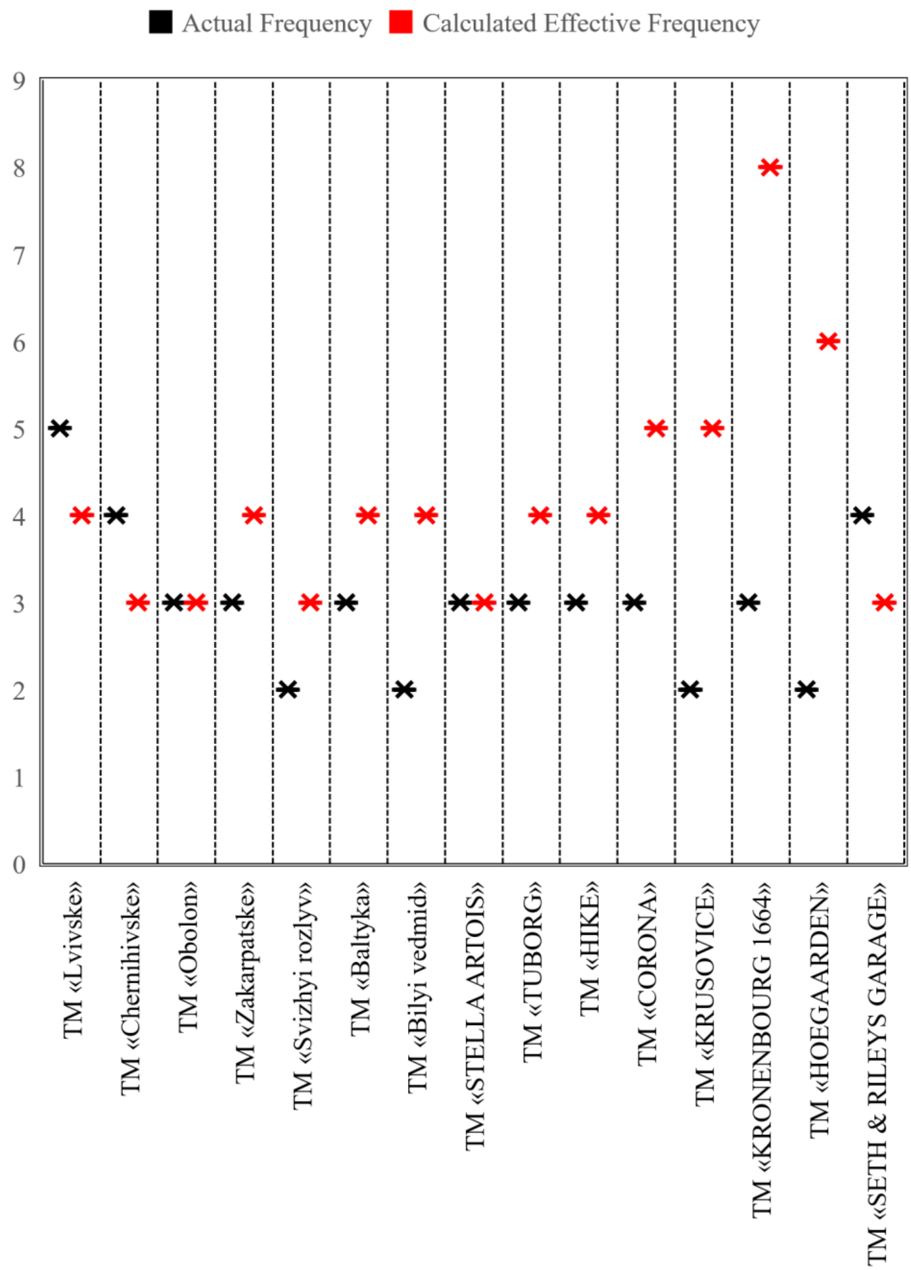


Figure 2. Comparison of actual and calculation effective of frequency of communication for instruments of on-line-advancement

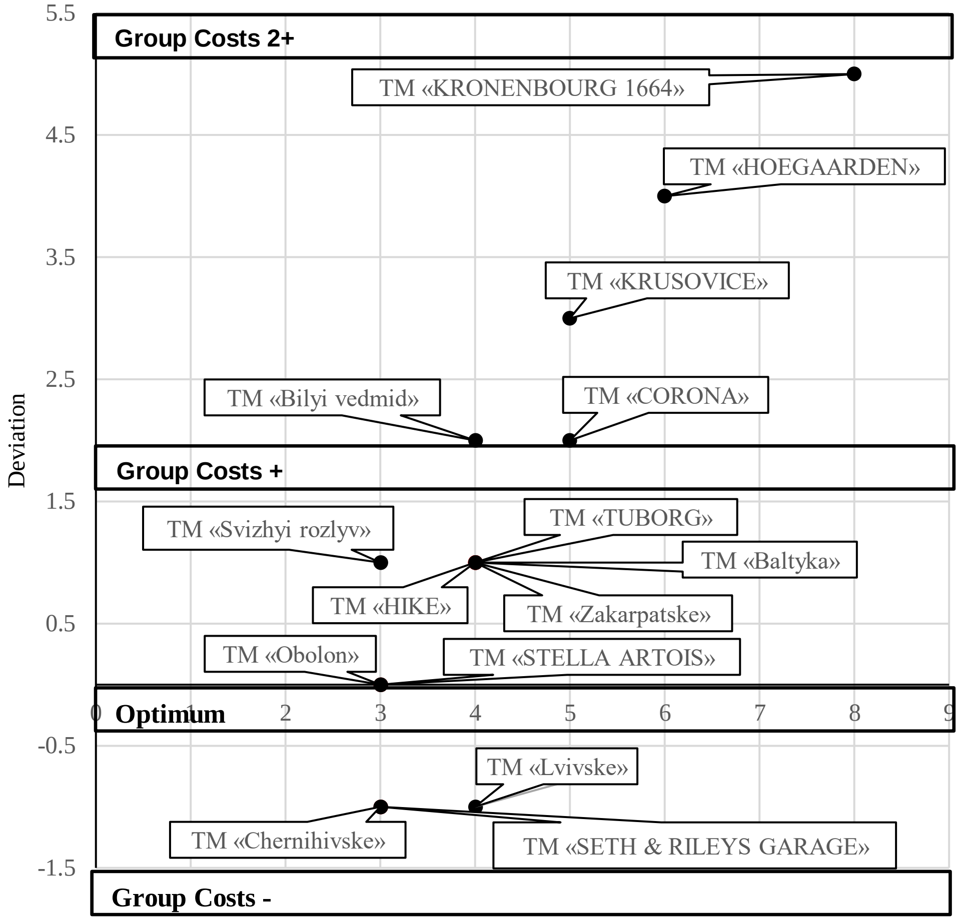


Figure 3. Matrix of the optimal communication frequency level

Taking into account other initial indexes, in particular additional coverage (unique displays), increase of the level of attention that influences both on communication and on economic efficiency is forecast.

«Group Optimum». As evidently from the results of analysis, TM «Obolon» (PJSC «Obolon»), TM «STELLA ARTOIS» (PJSC «ABinBev Ukraine») are only trademarks, in which the values of actual and calculative effective frequency that gives an opportunity to talk about accordance of communication strategy to the general situation on the market and fully takes into account the market, media and on-line media factors and factors of quality of advertisement messages.

«Group Expenses-». TM «Lvivske» (PJSC «Carlsberg Ukraine») and TM «Chernihivske» (PJSC «ABinBev Ukraine»), TM «SETH & RILEYS GARAGE» (PJSC «Carlsberg Ukraine») are included in this group. The marked brands potentially can communicate with less frequency - id est to spend less money, but to keep the influence on a consumer.

«Group Expenses +». Insufficient frequency of communication, taking into account all terms and factors of environment, have TM «Zakarpatske» (LLC «TPC «PPB»), TM «Svizhyi rozlyv» (LLC «TPC «PPB»), TM «Baltyka» (PJSC «Carlsberg Ukraine»), TM «TUBORG» (PJSC «Carlsberg Ukraine»), TM «HIKE» (PJSC «Obolon»), TM «Bilyi vedmid» (PJSC «ABinBev Ukraine»), TM «CORONA» (PJSC «ABinBev Ukraine»). Id est taking into account existing influence market, general, online-factors and factors of quality of advertisement message, frequency must be higher. Aims still can be achieved by means of the exceptionally use of instruments of on-line-advancement.

«Group Expenses 2+». Distant from optimal frequency have TM «KRUSOVICE» (LLC «TPC «PPB»), TM «KRONENBOURG 1664» (PJSC «Carlsberg Ukraine»), TM «HOEGAARDEN» (PJSC«ABinBev Ukraine»). Advancement of these brands exceptionally with the use of instruments of on - line advancement is insufficient - even at the terms of work on maximal frequency 5+, there is the requirement in additional contacts, id est for the achievement of communication and market aims it is expedient to use other channels of communications in media mix.

Using the obtained results, companies can optimize their media budget and increase the effectiveness of appeals.

Conclusions

1. The concept of effective frequency is one of the most important concepts in media planning, which allows you to determine the frequency of display of the advertising message, to form a positive perception of beer brands among consumers and to optimize the media budget for the promotion of beer brands both on the local market and on the international market.
2. To plan the frequency of advertised messages it is suggested to use the adapted Ostrow matrix to determine the effective frequency of communication with consumers of production of brewing industry. The "Market factors" block includes: market share of the brewing industry, loyalty to the beer brand, beer taste profile, voice share, the target audience of beer products, innovators and traditionalists. The block 'Factors of the quality of an advertising message includes: complexity of the marketing message for beer consumers, uniqueness (novelty) of beer products; degree of novelty of beer products, type of communication of beer producers, variability of the message, degree of wear and duration. «General Media factors» consist of competitive activity, Attention of audience of beer industry, Amount of channels. To the block of «Online media factors» are: Description of resources of placing, Use of videos-formats, Use of non-standard displays and formats, Scope of media channel, Type of placement, Accordance to general content of campaign.
3. For most beer brands of Ukrainian market planned and actual frequency of communication is investigational with the use of instruments of online-advancement for increasing the communication effectiveness of the advertised message. The effective frequency of displaying advertising messages to consumers in the representative sample of the enterprises in the brewing industry was determined in order to optimize the media budget.

4. The modified Ostrow matrix proposed by the authors can be used to determine the effective frequency of the advertised message not only for beer brands, but also for adaptation for brands of other activities in the food industry.

References

Aslam W., Farhat K., Arif I. (2021), Skippable advertisement versus full-length Advertisement: an empirical analysis in a developing economy, *Journal of Interactive Advertising*, 21(1), pp. 49–67, DOI:10.1080/15252019.2020.1852634

Betancur M.I., Motoki K., Spence C., Velasco C. (2020), Factors influencing the choice of beer: A review, *Food Research International*, 137, DOI: 10.1016/j.foodres.2020.109367

Budiawan R., Satria A., Simanjuntak M. (2017), The quasi experimental study of the influence of advertising creativity and exposure intensity toward purchasing action with AIDA approach, *Independent Journal of Management & Production*, 8(2), pp. 378–394, DOI:10.14807/ijmp.v8i2.526

Calder B. J., Malthouse E. C. (2005), Managing media and advertising change with integrated marketing, *Journal of Advertising Research*, 45, 4356–361, DOI: 10.1017/s0021849905050427.

Cannon H. M., Leckenby J. D., Abernethy A. (2002), Beyond effective frequency: Evaluating media schedules using frequency value planning, *Journal of Advertising Research*, 42(6), pp. 33–46.

Cannon H. M., Riordan E. A. (1994), Effective reach and frequency: does it really make sense?, *Journal of Advertising Research*, 34(2), pp. 19-29.

Cheong Y., De Gregorio F., Kim K. (2010), The power of reach and frequency in the age of digital advertising: offine and online media demand different metrics, *Journal of Advertising Research*, 50(4), pp. 403–415, DOI: 10.2501/S0021849910091555

Chu C. C., Changa C., Lee W. C. L., Nan Y. (2012), The effect of advertisement frequency on the advertisement attitude-the controlled effects of brand image and spokesperson's credibility, *Procedia – Social and Behavioral* Sciences, 57, pp. 352–359, DOI: 10.1016/j.sbspro.2012.09.1197

Cortinas M., Chocarro R., Elorz M. (2019), What do my channels provide to my customers?, *Omni-Channel Customers Versus Mono-channel Customers and the Impact of Distribution Services*, DOI: 10.2139/ssrn.3096461

Cramer-Flood E. (2021), *Worldwide ad spending 2021: A year for the record books*, Available at: https://bit.ly/3j6IWeg

Ehrenberg A.S.C. (1992), Comments on how advertising works, *The Journal of European Society for Opinion and Marketing Research*, 20(3), pp. 167–169.

Ephron E. (1998), Point of view: optimizers and media planning, *Journal of Advertising research*, pp. 47–47.

Felix R., Rauschnabel P. A., Hinsch C. (2017), Elements of strategic social media marketing, *Journal of Business Research*, 70(1), pp. 118–126, DOI: 10.1016/j.jbusres.2016.05.001

Fourberg N., Taş S., Wiewiorra L., Godlovitch I., De Streel A., Jacquemin H., Hill J., Nunu M., Bourguigon C., Jacques F., Ledger M., Lognoul M., (2021), Online advertising: the impact of targeted advertising on advertisers, market access and consumer choice, Publication for the committee on the Internal Market and Consumer Protection, Policy Department for Economic, Scientific and Quality of Life Policies, *European Parliament, Luxembourg*, Available at: https://bit.ly/3XYQA9M

Fournier S., Lee L. (2019), Getting Brand Communities Right, *Harvard Business Review*, Available at: https://hbr.org/2009/04/getting-brand-communities-right

Ham C., (2017), Exploring how consumers cope with online behavioral advertising. *International Journal of Advertising*, 36(4), pp. 632–658, DOI:10.1080/02650487.2016.1239878

Heath R. (2012), *Seducing the subconscious: The psychology of emotional influence in advertising*, John Wiley & Sons, DOI: 10.1002/9781119967637

Jeong Y., Sanders M., Zhao X. (2011), Bridging the gap between time and space: Examining the impact of commercial length and frequency on advertising effectiveness, *Journal of Marketing Communications*, 17(4), pp. 263-279, DOI: 10.1080/13527261003590259

Kapinus L., Rozumei S., Skrygun N., Semenenko K. (2020), Methodical approach to Evaluation of commodities` Advancement Efficiency using online-instruments. *AIC Economics and Management,* 2, pp. 157-167, DOI: 10.33245/2310-9262-2020-159-2-157–167

Kreshel P. J., Lancaster K. M., & Toomey M. A. (1985), How leading advertising agencies perceive effective reach and frequency, *Journal of Advertising*, 14(3), pp. 32–51.

Krugman H. E. (1972), Why three exposures may be enough, *Journal of Advertising Research* 12(6), pp. 11–14.

Leckenby J. D., Hong J. (1998), Using reach/frequency for web media planning, *Journal of Advertising Research*, 38(1), pp. 7–8.

Leckenby J. D., Kim H. (1994), How media directors view reach/frequency estimation: Now and a decade ago, *Journal of Advertising Research*, 34(5), pp. 9–22.

Leguina J.R., Rumin A.C., Rumin R.C. (2021), Optimizing the frequency capping: a robust and reliable methodology to define the number of ads to maximize ROAS, *Applied Sciences,* 11(15), pp. 66–88, DOI: 10.3390/app11156688

Makienko I. (2012), Effective frequency estimates in local media planning practice, *Journal of Targeting, Measurement and Analysis for Marketing*, 20, pp. 57–65, DOI: 10.1057/jt.2012.1

McDonald C. (1970), What is the short-term effect of advertising?, *ESOMAR Congress*, Barcelona, Spain.

Miller S., Berry L. (1998), Brand salience versus brand image: two theories of advertising effectiveness, *Journal of Advertising Research,* 38(5), pp. 77–84.

Naples M. J. (1997), Effective frequency: then and now, *Journal of Advertising Research,* 37(4), pp. 7–13.

Naples M. J. (1979), *Effective Frequency: The Relationship between Frequency and Advertising Effectiveness*, Association of National Advertisers, Business & Economics New York, p. 140.

Ostrow J.W. (1984), Setting frequency levels: an art or a science?, *Journal of Advertising Research,* 24(4), pp. 9–11.

Pedreño-Santos A., Garcia-Madariaga J. (2022), Analysis of effective recall in radio advertising, *Journal of Communication Management*, DOI: 10.1108/JCOM-09-2021-0104

Pryimachuk T., Protsenko A., Rudyk R., Shtanko T. (2018), Beer and hop branches of Ukraine: conjuncture and integration, *Visnyk Agrarnoi Nauky*, 4(781), pp. 61–67.

Rodgers Sh., Thorson E. (2019), *Advertising Theory,* New York, DOI: 10.4324/9781351208314

Schmidt S., Eisend M. (2015), Advertising repetition: a meta-analysis on effective frequency in advertising, *Journal of Advertising,* 44, pp. 415–428, DOI: 10.1080/00913367.2015.1018460

Schwarzl S., Grabovska M. (2015), Online marketing strategies: the future is here, *Journal of International Studies,* 2(8), pp. 187–196, DOI: 10.14254/2071-8330.2015/8-2/16

Semenenko K. Iu., Yurchenko V.I., Skryhun N.P. (2019), Marketing activity in social networks facebook and Instagram, *Scientific Notes of Taurida National V.I. Vernadsky University,* 30(69), pp. 164–168.

Simon H. A. (1978), Information-processing theory of human problem solving, *Handbook of learning and cognitive processes,* 5, pp. 271–295.

Skrygun N.P., Semenenko K.Yu., Pirnak M.V. (2016), The essence of marketing communication and the relationship of its elements, *Journal of Volyn Institute for Economics and Management,* 15, pp. 271–279.

Stewart D. W. (1989), Measures, methods, and models in advertising research, *Journal of Advertising Research,* 29(3), 54–60.

Strycharz J., Segijn C.M. (2022), The future of dataveillance in advertising theory and practice, *Journal of Advertising,* 51, pp. 574–591, DOI: 10.1080/00913367.2022.2109781

Tellis G. J. (1997), Effective frequency: one exposure or three factors?, *Journal of Advertising Research*, pp. 75–80.

Watrobski J., Jankowski J., Ziemba P. (2016), Multistage performance modelling in digital marketing management, *Economics and Sociology,* 9(2), pp. 101–119, DOI: 10.14254/2071-789X.2016/9/2/7.

Weinberg P., Gottwald W. (1982), Impulsive consumer buying as a result of emotions, *Journal of Business Research,* 10(1), pp. 43-57, DOI: 10.1016/0148-2963(82)90016-9.

Xiao M., Wang R., Chan-Olmsted S. (2018), Factors affecting YouTube influencer marketing credibility: a heuristic-systematic model, *Journal of media business studies,* 15(3), pp. 188–213, DOI: 10.1080/16522354.2018.1501146

Yasmin A., Tasneem S., Fatema K. (2015), Effectiveness of digital marketing in the challenging age: An empirical study, *International Journal of Management Science and Business Administration*, 1(5), pp. 69–80, DOI:10.18775/ijmsba.1849-5664-5419.2014.15.1006

Zanuddin H. (2004), Media impact: effectiveness of reach & frequency in media buying pattern and audience analysis, *Journal Pengajian Media Malaysia*, 6(1), pp. 25–37.

Анотації

Харчові технології

Технологічні функції гідролізованого концентрату сироватки у складі морозива

Олександр Шевченко[1], Артур Михалевич[1], Галина Поліщук[1],
Магдалена Буньовська[2], Оксана Басс[1], Ульяна Бандура[1]
1 – Національний університет харчових технологій, Київ, Україна
2 – Жешувський університет, Жешув, Польща

Вступ. У статті досліджено показники якості морозива нежирного з різним співвідношенням між цукром і гідролізованим та негідролізованим концентратами демінералізованої підсирної молочної сироватки.

Матеріали і методи. Ступінь гідролізу лактози визначали йодометричним і рефрактометричним методами, активність води у сумішах − на аналізаторі активності води «HygroLab 2», реологічні характеристики – на ротаційному віскозиметрі, пінозбитість і піностійкість сумішей морозива, швидкість танення – модифікованими методами, органолептичні показниками – дескрипторно-інтегральним методом. Масову частку білка, сухих речовин, збитість, опір таненню в морозиві визначали за допомогою загальновідомих методів.

Результати і обговорення. На основі проведеного розрахунку ступеня солодкості концентратів сироватки з урахуванням масової частки сухих речовин, ступеня гідролізу лактози та відомих значень відносної солодкості цукру, лактози, глюкози і галактози було обрано концентрат із вмістом сухих речовин 40% для застосування в рецептурному складі морозива. За результатами дослідження комплексу показників якості сумішей морозива встановлено, що концентрат демінералізованої гідролізованої сироватки з масовою часткою сухих речовин 40% може замінювати до 42% цукру у складі морозива зі збереженням визначеного для морозива виду ступеня солодкості в діапазоні від 0,8 до 0,9. За в'язкісно-швидкісними характеристиками суміш морозива нежирного з концентратом демінералізованої гідролізованої сироватки віднесено до систем з вираженою коагуляційною структурою з виявленням тиксотропних властивостей. Морозиво на основі гідролізованого концентрату сироватки містить 3,3% сироваткових білків, що відповідає стандартному хімічному складу морозива. Високий вміст продуктів гідролізу лактози в морозиві підвищує збитість, але знижує опір таненню морозива, що треба враховувати під час технологічного процесу та при виборі споживчої тари.

Висновки. Доведено доцільність застосування гідролізованого концентрату підсирної сироватки з масовою часткою сухих речовин 40% як підсолоджуючого і білоквмісного інгредієнта у складі морозива нежирного, що виявляє виражені технологічні властивості.

Ключові слова: *сироватка, морозиво, лактоза, солодкість, тиксотропність.*

Управління побічними продуктами перероблення яблук і винограду. Огляд

Вікторія Стаматовська[1], Гьоре Наков[2]
1 –Університет Бітоли, Македонія
2 – Технічний університет Софії, Слівенський коледж, Болгарія

Вступ. Субпродукти переробки яблук і винограду можуть бути сировиною для виробництва функціональних продуктів. При цьому зберігається навколишнє середовище, а харчові продукти збагачуються важливими поживними речовинами.

Матеріали і методи. Систематизація останніх наукових досліджень щодо поводження з відходами виробництва яблучного соку і виноградного вина.

Результати і обговорення. Побічні продукти перероблення яблук і винограду містять важливі поживні речовини, такі як клітковина, мінерали, вітаміни, поліфеноли, і мають високу антиоксидантну активність. В останні роки дослідники активно вивчали використання цього виду відходів у приготуванні різних харчових продуктів (бісквітів, печива, тортів, хліба, макаронних виробів, локшини, йогурту, сиру, кефіру, салямі, ковбас, пиріжків і бургерів). При заміні звичайного борошна побічними продуктами перероблення яблук і винограду спостерігаються варіації. Так, для зернових продуктів мінімальний відсоток заміни становив 1%, а максимальний – 100%. Для м'ясних продуктів відсоток доданих субпродуктів перероблення яблук і винограду коливався від 1 до 20%, а для молочних – від 0,2 до 10%. Зафіксовано покращення якості поживних речовин із додаванням побічних продуктів перероблення яблук і винограду, наприклад, збільшення клітковини, загального вмісту поліфенолів, флавоноїдів, антоціанів і мінеральних речовин, а також антиоксидантної активності. Включення побічних продуктів перероблення яблук і винограду призводить до зміни об'єму або висоти виробів (бісквітів, печива, тортів і хліба), зміни консистенції (твердість, хрусткість), зовнішнього вигляду (властивості поверхні, колір, густина), а також інтенсивності запаху і смаку. Виявлено, що оптимальний час приготування пасти/локшини/спагеті зменшився, а втрати під час варіння зросли зі збільшенням кількості включених відходів перероблення яблук і винограду. Додавання цих побічних продуктів зменшило час бродіння та синерезис під час зберігання йогурту. Встановлено, що додавання субпродуктів перероблення яблук і винограду в м'ясопродукти сприяє підвищенню виходу під час варіння, стабільності емульсії, активності поглинання радикалів і зниженню pH.

Висновки. Використання відходів перероблення яблук і винограду в харчовій промисловості – це можливість зменшити забруднення навколишнього середовища, створити нові функціональні та інноваційні харчові харчування, які будуть збагачені важливими поживними та біологічно активними речовинами.

Ключові слова: *субпродукти, виноград, яблуко, вичавки, відходи, функціональний.*

Вплив техніко-технологічних параметрів на процес лущення ячменю

Євген Харченко[1], Амелія Букулєй[2], Валентин Чорний[1], Андрій Шаран[1]
1 – Національний університет харчових технологій, Київ, Україна
2 – Університет «Штефана чел Маре», Сучава, Румунія

Вступ. Мета – дослідити залежність індексу лущення від тривалості обробки, вологості та крупності зерна ячменю, частоти обертання абразивних дисків, зернистості та маси зерна, завантаженого в лущильник, а також коефіцієнта завантаження робочої камери машини.

Матеріали і методи. Лущення зерна здійснювалося в лущильнику УЛЗ-1 при швидкості обертання абразивних дисків 29,6±0,015 $с^{-1}$ (1775±0,9 об/хв) та 42,3±0,013 $с^{-1}$ (2540±0,8 об/хв). Виділення лузги та мучки із зерна ядра ячменю здійснювали в лабораторному аспіраційному каналі із шириною 60 мм.

Результати і обговорення. Дослідження показали, що збільшення тривалості лущення, маси зерна ячменю, яка завантажена в лущильник, частоти обертання абразивних дисків і коефіцієнта завантаження робочої камери лущильника призводить до збільшення індексу лущення. Існує нелінійна залежність між коефіцієнтом завантаження робочої камери лущильника з точкою мінімуму індексу лущення для крупної фракції 0,27–0,28, для дрібної фракції ячменю – 0,24–0,25.

Вплив маси ячменю і коефіцієнта завантаження робочої камери лущильника на індекс лущення відбувається за криволінійною залежністю з точкою мінімуму для крупної фракції ячменю 0,27–0,28, для дрібної – 0,24–0,25. Збільшення тривалості обробки і коефіцієнта завантаження робочої камери лущильника призводить до збільшення індексу лущення, але при цьому точка мінімуму індексу лущення зменшується з 0,29 до 0,25.

При збільшенні розміру зерна ячменю індекс лущення знижується. Збільшення вологості ячменю призводить до зниження індексу лущення за лінійною залежністю як для крупної, так і дрібної фракції ячменю. При цьому дрібна фракція має більші значення індексу лущення, ніж крупна. Вплив вологості зерна на індекс лущення ячменю має лінійну залежність як для крупної, так і для дрібної фракції. Зі збільшенням вологості індекс лущення лінійно зменшується, але при цьому крупна фракція ячменю має більш низькі значення індексу лущення, ніж дрібна.

Збільшення зернистості абразивних дисків призводить до зниження індексу лущення за криволінійною залежністю. При зернистості 80 індекс лущення приймає постійне значення і його зміна залежить від тривалості обробки зерна.

Висновки. Дослідженнями встановлено, що вплив технологічних параметрів зерна ячменю на індекс лущення має лінійні залежності, а параметри машини впливають на індекс лущення за криволінійними залежностями. Результати цього дослідженнями необхідно враховувати при оцінюванні ефективності лущення та подальшому розробленні моделі процесу.

Ключові слова: *ячмінь, лущення, волога, крупка, лушпиння.*

Вплив шипшиновго борошна на властивості пшеничного тіста і хліба

Росен Чочков[1], Денка Златева[2],
Петя Іванова[1], Дана Стефанова[2]
1 – Університет харчових технологій, Пловдив, Болгарія
2 – Економічний університет, Варна, Болгарія

Вступ. Метою дослідження було визначення впливу шипшинового борошна на властивості пшеничного тіста і хліба.

Матеріали і методи. Хліб готували з пшеничного борошна з додаванням борошна шипшини в кількості 5, 10 і 15 % замість однакової кількості пшеничного борошна. Використано загальноприйняті методи оцінки хліба.

Результати і обговорення. Додавання до пшеничного борошна різної кількості шипшинового борошна впливало на інтенсивність газоутворення, зі збільшенням вмісту шипшинового борошна інтенсивність газоутворення зменшувалася. При додаванні 5% борошна із шипшини суттєвого погіршення газоутворення не спостерігалось. Введення шипшинового борошна в пшеничне тісто призвело до зниження водопоглинання і ступеня розм'якшення, а найнижчі результати були виявлені у зразка з додаванням 15% шипшинового борошна. За часом формування і консистенцією тіста істотних відмінностей між зразками не було. Стабільність тіста була вищою у зразках, що містять шипшинове борошно, найвище значення було для зразка з 5% шипшинового борошна. Зі збільшенням кількості шипшинового борошна колірні характеристики тіста та хліба знижувалися. Більш темний колір зразків, збагачених борошном шипшини, міг бути пов'язаний з оригінальним кольором волокна шипшини, який близький до коричневого і злегка червонуватий. Заміна пшеничного борошна борошном із шипшини призвела до зменшення об'єму, питомого об'єму, співвідношення висота/діаметр та втрати пшеничного хліба під час випіканні. Деякі сенсорні параметри хліба (колір скоринки, аромат і смак) у зразках із додаванням шипшинового борошна були високо оцінені експертами порівняно з контрольним зразком, незалежно від кількості доданого шипшинового борошна.

Висновки. Шипшинове борошно можна успішно використовувати як добавку до рецептури пшеничного хліба. Сенсорні показники зразків хліба із шипшиновим борошном за такими властивостями, як колір скоринки, аромат і смак, мали вищі значення, ніж у контрольному зразку.

Ключові слова: *пшеничний хліб, шипшина, борошно, реологія.*

Використання люпинового борошна та пюре кавбуза в технології хліба

Світлана Бажай-Жежерун, Галина Сімахіна,
Людмила Береза-Кіндзерська, Тетяна Романовська
Національний університет харчових технологій, Київ, Україна

Вступ. Досліджено вплив рослинних збагачувачів: пюре кавбуза та борошна безалкалоїдного люпину на харчову та біологічну цінність пшеничного хліба, його сорбційну здатність щодо токсичних іонів свинцю.

Матеріали і методи. Вміст білка визначали методом Бредфорда, крохмалю – поляриметрично; жиру – вичерпним екстрагуванням хімічно чистим гексаном; вітамінів Е, Р, β–каротину – колориметрично; вітаміну С – титриметрично; $B_{1,}$ B_2 – флуорометрично; клітковини – кислотним гідролізом; пектину – кальцієво-пектатним методом. Кількість поглинутого свинцю визначали методом «мокрого спалювання».

Результати і обговорення. Пюре кавбуза є багатим джерелом речовин з антиоксидантною активністю: β-каротину – 13,4 мг, Р (рутину) – 45,4 мг, фенольних сполук – 283 мг тощо; а також природних харчових сорбентів – клітковини 1,7 г, пектину – 1,5 г на 100 г продукту (вологість 83,1%). За органолептичними та фізико-хімічними показниками якості пюре кавбуза може бути технологічним складником для виробництва оздоровчих продуктів.

Люпинове борошно містить у 3,9 раза більше білка, у 40 разів більше клітковини, у 10,5 пектинових речовин порівняно з пшеничним борошном; значну кількість токоферолів – 12,8 мг, β-каротину – 0,52 мг, вітаміну С – 35, 84 мг на 100 г продукту (вологість 9,5%).

Включення 4–7% борошна люпину та 3–5% пюре кавбуза до рецептури пшеничного хліба надає можливість отримати хліб оздоровчого призначення, у якому вміст білка на 22–32%, клітковини у два – три рази, токоферолів у 9 разів є вищим ніж у контролі, за умови прийнятних фізико-хімічних та органолептичних показників продукту. 100 г розробленого хліба дає змогу забезпечити 23% мінімальної норми споживання пектину, 6% добової потреби у вітаміні Е; 13,8% у B_1, 14% у β-каротині; 6,6% у флавоноїдах, які у пшеничному хлібі відсутні. Збагачений хліб має у 25–30 разів вищу сорбційну здатність до токсичних іонів двовалентного свинцю, ніж пшеничний хліб.

Висновки. Рекомендовано використання пюре кавбуза та борошна безалкалоїдних сортів люпину для виробництва пшеничного хліба підвищеної харчової цінності та оздоровчого спрямування.

Ключові слова: *кавбуз, люпин, борошно, хліб.*

Вплив комплексного хлібопекарського поліпшувача на подовження свіжості булочних виробів зі зниженим вмістом солі

Олена Білик, Віктор Стабніков, Оксана Вашека,
Юлія Бондаренко, Оксана Кочубей-Литвиненко
Національний університет харчових технологій, Київ, Україна

Вступ. Метою дослідження є визначення впливу комплексного хлібопекарського поліпшувача на подовження свіжості булочних виробів зі зниженим вмістом солі згідно з принципами lean-виробництва.

Матеріали і методи. Здійснювали соціологічні дослідження вимог до якості хлібобулочних виробів. Розробляли рецептуру комплексного хлібопекарського поліпшувача «Мінеральна свіжість +» та встановлювали оптимальне дозування. Досліджували вплив розробленого поліпшувача на якість булочних виробів, у рецептурі яких вміст солі становить 0,5 % до маси борошна, та вплив на процеси черствіння виробів під час зберігання.

Результати і обговорення. Згідно із соціологічними дослідженнями, для споживачів небажаним є наявність у хлібобулочних виробах інгредієнтів синтетичного походження та швидка втрата ними свіжості. Для задоволення потреб споживачів передбачено застосування lean-виробництва під час виготовлення хлібобулочних виробів, що полягає у зниженні технологічних затрат і втрат за рахунок використання розробленого поліпшувача. Розроблено рецептуру комплексного хлібопекарського поліпшувача «Мінеральна свіжість +», який призначений для інтенсифікації технологічного процесу виробництва, покращання споживчих властивостей і подовження свіжості булочних виробів, у рецептурі яких зменшено вміст солі на 0,5 %. До складу поліпшувача включено харчові добавки, які мають статус GRAS, тобто безпечні. За дозування 2,0% до маси борошна подовжується тривалість збереження хлібобулочними виробами свіжості. Підтвердженням цього є більший у виробі з поліпшувачем, порівняно з контролем, на 65,2–75,6 % вміст декстринів, менший підскоринковий шар на 72 год зберігання виробів і зміни в структурі м’якушки, яка складається з вкраплених набухлих і частково клейстеризованих зерен крохмалю, що огорнуті суцільною масою коагульованих білків.

Висновки. Використання розробленого поліпшувача «Мінеральна свіжість +» у виготовленні булочних виробів забезпечує високу задоволеність споживачів.

Ключові слова: *булочні вироби, lean-виробництво, черствіння, поліпшувач, деформація, добавки.*

Використання біоактивних властивостей рослинних екстрактів для підвищення стійкості при зберіганні м'яса індички механічної сепарації

Василь Пасічний[1], Василь Тищенко[2],
Наталія Божко[3], Ольга Коваль[1], Андрій Маринін[1]
1 – Національний університет харчових технологій, Київ, Україна
2 – Сумський національний аграрний університет, Суми, Україна
3 – Сумський державний університет, Суми, Україна

Вступ. Метою статті було дослідження впливу природних антиоксидантів, зокрема екстракту чорноплідної горобини, екстракту журавлини, екстракту листя смородини для стабілізації процесів окислення жирового комплексу МПМО індика в процесі зберігання.

Матеріали і методи. Предметом дослідження було м'ясо індика механічного обвалювання. Як антиокислювальний препарат використовували комерційні рослинні екстракти з вичавок чорноплідної горобини (*Aronia melanocarpa*), екстракт із вичавок журавлини (*Vaccinium Oxycoccus)*, екстракт листя чорної смородини (*Ribes nigrum L.*). Протягом терміну зберігання в зразках досліджували динаміку окислювальних процесів і визначали кислотне, перекисне та тіобарбітурове числа.

Результати і обговорення. Хімічний склад м'яса індичого механічного обвалювання відрізняється високим вмістом протеїну (14,22%) і жиру (17,3%), що підвищує ризик окислювального псування під час реалізації і зберігання. Використання рослинних екстрактів дало змогу знизити інтенсивність окислення ліпідів у м'ясі індичому механічного обвалювання під час зберігання в замороженому стані протягом 9 тижнів. У кінці досліду концентрація вільних жирних кислот у контролі була найвищою і становила 3,81±0,02 мг КОН, що на 131,83% вище, ніж у зразку з екстрактом листя смородини, в 4,76 раза вище, ніж у зразку з екстрактом журавлини, і в 7,33 раза вище, ніж у зразку з екстрактом чорноплідної горобини. Показано, що екстракти з вичавок ягід чорноплідної горобини і журавлини уповільнили гідролітичні зміни у жирах продукту на 81,20 і 76,47% відповідно. Додавання екстракту чорноплідної горобини і журавлини в концентрації 0,2% сприяло зниженню перекисного числа через два місяці зберігання м'яса індичого механічного обвалювання до 0,057–0,060 J_2 %, що майже вдвічі уповільнило синтез перекисів у продукті. Встановлено, що внесення екстрактів чорноплідної горобини і журавлини в концентрації 0,2–0,3% гальмує накопичення вторинних продуктів окислення ліпідів на 35,10–39,36%.

Висновок. Порівняльний аналіз і комплексна оцінка вмісту продуктів окиснення в контрольних і дослідних зразках об'єктивно свідчать про позитивний вплив природних антиоксидантів на окислювальне псування МПМО індички за умов зберігання протягом установленого терміну.

Ключові слова: *індичка, м'ясо, механічна сепарація, чорноплідна горобина, журавлина, чорна смородина, антиоксидант.*

Економіка і управління

Ефективна частота показу рекламного повідомлення споживачам пивних брендів у цифрових медіа

Катерина Семененко[1], Лариса Капінус[1], Ірина Бойко[1],
Володимир Кучеренко[2], Наталія Скригун[1]
1 – Національний університет харчових технологій, Київ, Україна
2 – Українська корпорація виноградарства і виноробної промисловості «Укрвинпром»

Вступ. Дослідження спрямоване на визначення ефективної частоти показу рекламних повідомлень споживачам у репрезентативній вибірці підприємств пивоварної галузі для оптимізації медійного бюджету.

Матеріали і методи. Дослідження ґрунтується на результатах праць науковців з питань розвитку ринку пива та цифрової економіки, теорій частоти рекламних повідомлень, маркетингових досліджень найбільших пивоварних компаній та їх брендів для визначення мінімального порогу ефективної частоти рекламних звернень до споживачів пива.

Результати і обговорення. Частота показу комунікаційного повідомлення визначає не лише ефективність звернень до споживача, але й витрати на медійний бюджет, проте наразі відсутня єдина точка зору на цю проблему в наукових публікаціях. Як недостатня кількість звернень, так і надмірна частота призводять до неефективного використання бюджету. Ефективна частота повідомлення впливає не тільки на купівельну поведінку споживача та показники здоров’я бренду, а й дає змогу оптимізувати медійний бюджет. Визначено, що найчастіше в медіаплануванні використовують ефективну частотну стратегію «три плюс».

З метою визначення ефективної частоти комунікацій зі споживачами для інструментів онлайн-просування пива запропоновано модифіковану матрицю Остроу. Удосконалено блоки факторів, які впливають на просування пива на споживчий ринок: «Ринкові чинники», «Чинники якості рекламного повідомлення», «Загальні медіачинники». Додано блок «Онлайн-медіачинники», куди увійшли такі показники, як характеристика ресурсів розміщення, використання соціальних медіа, використання відеоформатів, використання нестандартних проявів і форматів, охоплення медіаканалу, тип розміщення, відповідність загальному контенту кампанії.

Адаптація вдосконаленої матриці відбулась на прикладі найбільших пивних брендів ринку, для яких було визначено ефективну частоту повторень комунікаційного повідомлення та здійснено порівняння з фактичною, що дало змогу згрупувати бренди в чотири групи з позиції стратегії подальших витрат на розміщення рекламних повідомлень в мережі Інтернет.

Висновки. Для планування частоти рекламних повідомлень пропонується використовувати модифіковану матрицю визначення ефективної частоти комунікацій зі споживачами продукції пивних брендів, що дасть змогу оптимізувати медіа-бюджет.

Ключові слова: *пиво, бренд, маркетинг, онлайн-реклама, медіа.*

Instructions for authors

Dear colleagues!

The Editorial Board of scientific periodical
"**Ukrainian Food Journal**"
invites you for publication of your research results.

A manuscript should describe the research work that has not been published before and is not under consideration for publication anywhere else. Submission of the manuscript implies that its publication has been approved by all co-authors as well as by the responsible authorities at the institute where the work has been carried out.

It is mandatory to include a covering letter to the editor which includes short information about the subject of the research, its novelty and significance; state that all the authors agree to submit this paper to Ukrainian Food Journal; that it is the original work of the authors.

Manuscript requirements

Authors must prepare the manuscript according to the guide for authors. Editors reserve the right to adjust the style to certain standards of uniformity.

Language – English

Manuscripts should be submitted in Word.

Use 1.0 spacing and 2 cm margins.

Use a normal font 14-point Times New Roman for text, tables, and sings on figures, 1.0 line intervals.

Present tables and figures in the text of manuscript.

Consult a recent issue of the journal for a style check.

Number all pages consecutively.

Abbreviations should be defined on first appearance in text and used consistently thereafter. No abbreviation should be used in title and section headings.

Please submit math equations as editable text and not as images (It is recommend software application MathType or Microsoft Equation Editor)

Minimal size of the article (without the Abstract and References) is 10 pages. For review article is 25 pages (without the Abstract and References).

Manuscript should include:

Title (should be concise and informative). Avoid abbreviations in it.

Authors' information: the name(s) of the author(s); the affiliation(s) of the author(s), city, country. One author has been designated as the corresponding author with e-mail address. If available, the 16-digit ORCID of the author(s).

Declaration of interest

Author contributions

Abstract. The **abstract** should contain the following mandatory parts:

Introduction provides a rationale for the study (2–3 lines).

Materials and methods briefly describe the materials and methods used in the study (3–5 lines).

Results and discussion describe the main findings (20–26 lines).

Conclusion provides the main conclusions (2–3 lines).

The abstract should not contain any undefined abbreviations or references to the articles.

Keywords. Immediately after the abstract provide 4 to 6 keywords.

Text of manuscript

References

Manuscripts should be divided into the following sections:

- **Introduction**
- **Materials and methods**
- **Results and discussion**
- **Conclusions**
- **References**

Introduction. Provide a background avoiding a detailed review of literature and declare the aim of the present research. Identify unexplored questions, prove the relevance of the topic. This should be not more than 1.5 pages.

Materials and methods. Describe sufficient details to allow an independent researcher to repeat the work. Indicate the reference for methods that are already published and just summarize them. Only new techniques need be described. Give description to modifications of existing methods.

Results and discussion. Results should be presented clearly and concisely with tables and/or figures, and the significance of the findings should be discussed with comparison with existing in literature data.

Conclusions. The main conclusions should be drawn from results and be presented in a short Conclusions section.

Acknowledgments(if necessary)**.** Acknowledgments of people, grants, or funds should be placed in a separate section. List here those persons who provided help during the research. The names of funding organizations should be written in full.

Divide your article into sections and into subsections if necessary. Any subsection should have a brief heading.

References

Please, check references carefully.

The list of references should include works that are cited in the text and that have been published or accepted for publication.

All references mentioned in the reference list are cited in the text, and vice versa.

Cite references in the text by name and year in parentheses. Some examples:

(Drobot, 2008); (Qi and Zhou, 2012); (Bolarinwa et al., 2019; Rabie et al., 2020; Sengev et al., 2013).

Reference list should be alphabetized by the last name of the first author of each work.

If available, please always include DOIs links in the reference list.

Reference style

Journal article

Please follow this style and order: author's surname, initial(s), year of publication (in brackets), paper title, *journal title (in italic)*, volume number (issue), first and last page numbers, e.g.:

Popovici C., Gitin L., Alexe P. (2013), Characterization of walnut (*Juglans regia* L.) green husk extract obtained by supercritical carbon dioxide fluid extraction, *Journal of Food and Packaging Science, Technique and Technologies*, 2(2), pp. 104-108, DOI: 10.1016/j.jece.2020.103776

Journal names should not be abbreviated.

Book

Deegan C. (2000), *Financial Accounting Theory*, McGraw-Hill Book Company, Sydney.

Book chapter in an edited book

Coffin J.M. (1999), Molecular biology of HIV, In: Crandell K.A. ed., *The Evolution of HIV*, Johns Hopkins Press, Baltimore, pp. 3–40.

Fordyce F.M. (2013), Selenium deficiency and toxicity in the environment. In: Selinus O. (ed.), *Essentials of Medical Geology*, pp. 375–416, Springer, DOI: 10.1007/978-94-007-4375-5_16

Online document

Mendeley J.A., Thomson, M., Coyne R.P. (2017), *How and When to Reference*, Available at: https://www.howandwhentoreference.com

Conference paper

Arych M. (2018), Insurance's impact on food safety and food security, *Resource and Energy Saving Technologies of Production and Packing of Food Products as the Main Fundamentals of Their Competitiveness: Proceedings of the 7th International Specialized Scientific and Practical Conference, September 13, 2018,* NUFT, Kyiv, pp. 52-57.

Figures

All figures should be made in graphic editor using a font Arial.

The font size on the figures and the text of the article should be the same.

Black and white graphic with no shading should be used.

The figure elements (lines, grid, and text) should be presented in black (not gray) colour.

Figure parts should be denoted by lowercase letters (a, b, etc.).

All figures are to be numbered using Arabic numerals.

Figures should be cited in text in consecutive numerical order.

Place figure after its first mentioned in the text.

Figure captions begin with the term Figure in bold type, followed by the figure number, also in bold type.

Each figure should have a caption describing what the figure depicts in bold type.

Supply all figures and EXCEL format files with graphs additionally as separate files.

Photos are not advisable to be used.

If you include figures that have already been published elsewhere, you must obtain permission from the copyright owner(s).

Tables

Number tables consecutively in accordance with their appearance in the text.

Place footnotes to tables below the table body and indicate them with superscript lowercase letters.

Place table after its first mentioned in the text.

Ensure that the data presented in tables do not duplicate results described elsewhere in the article.

Suggesting / excluding reviewers

Authors are welcome to suggest reviewers and/or request the exclusion of certain individuals when they submit their manuscripts.

When suggesting reviewers, authors should make sure they are totally independent and not connected to the work in any way. When suggesting reviewers, the Corresponding Author must provide an institutional email address for each suggested reviewer. Please note that the Journal may not use the suggestions, but suggestions are appreciated and may help facilitate the peer review process.

Submission

Email for all submissions and other inquiries:

ufj_nuft@meta.ua

Шановні колеги!

Редакційна колегія наукового періодичного видання «**Ukrainian Food Journal**» запрошує Вас до публікації результатів наукових досліджень.

Вимоги до оформлення статей

Мова статей – англійська.

Мінімальний обсяг статті – **10 сторінок** формату А4 (без врахування анотацій і списку літератури)**.**

Для всіх елементів статті шрифт – **Times New Roman**, кегль – **14**, інтервал – 1.

Всі поля сторінки – по 2 см.

Структура статті:

1**.** УДК**.**
2. **Назва статті.**
3. Автори статті (ім'я та прізвище повністю, приклад: Денис Озерянко).
4. *Установа, в якій виконана робота*.
5. Анотація. **Обов'язкова** структура анотації:
   - Вступ (2–3 рядки).
   - Матеріали та методи (до 5 рядків)
   - Результати та обговорення (пів сторінки).
   - Висновки (2–3 рядки).
6. Ключові слова (3–5 слів, але не словосполучень).

Пункти 2–6 виконати англійською і українською мовами.

7. Основний текст статті. Має включати такі обов'язкові розділи:
   - Вступ
   - Матеріали та методи
   - Результати та обговорення
   - Висновки
   - Література.

За необхідності можна додавати інші розділи та розбивати їх на підрозділи.

8. Авторська довідка (Прізвище, ім'я та по батькові, вчений ступінь та звання, місце роботи, електронна адреса або телефон).
9. Контактні дані автора, до якого за необхідності буде звертатись редакція журналу.

Рисунки виконуються якісно. Скановані рисунки не приймаються. Розмір тексту на рисунках повинен бути **співрозмірним** (!) тексту статті. **Фотографії можна використовувати лише за їх значної наукової цінності.**

Фон графіків, діаграм – лише білий. Колір елементів рисунку (лінії, сітка, текст) – чорний (не сірий).

Рисунки та графіки EXCEL з графіками додатково подаються в окремих файлах.

Скорочені назви фізичних величин в тексті та на графіках позначаються латинськими літерами відповідно до системи СІ.

У списку літератури повинні переважати англомовні статті та монографії, які опубліковані після 2010 року.

Оформлення цитат у тексті статті:

Кількість авторів статті	Приклад цитування у тексті
1 автор	(Arych, 2019)
2 автора	(Kuievda and Bront, 2020)
3 і більше авторів	(Bazopol et al., 2022)

Приклад тексту із цитуванням: It is known (Arych, 2019; Bazopol et al., 2022), the product yield depends on temperature, but, there are some exceptions (Kuievda and Bront, 2020).

У цитуваннях необхідно вказувати одне джерело, звідки взято інформацію.

Список літератури сортується за алфавітом, літературні джерела не нумеруються.

Правила оформлення списку літератури

В Ukrainian Food Journalвзято за основу загальноприйняте в світі спрощене оформлення списку літератури згідно стандарту Garvard. Всі елементи посилання розділяються **лише комами**.

1. Посилання на статтю:

Автори А.А. (рік видання), Назва статті, *Назва журналу (курсивом)*, Том (номер), сторінки, DOI.

Ініціали пишуться після прізвища.

Всі елементи посилання розділяються комами.

Приклад:

Popovici C., Gitin L., Alexe P. (2013), Characterization of walnut (*Juglans regia* L.) green husk extract obtained by supercritical carbon dioxide fluid extraction, *Journal of Food and Packaging Science, Technique and Technologies*, 2(2), pp. 104–108, DOI: 5533.935-3.

2. Посилання на книгу:

Автори (рік), *Назва книги (курсивом)*, Видавництво, Місто.

Ініціали пишуться після прізвища.

Всі елементи посилання розділяються комами.

Приклад:

Deegan C. (2000), *Financial Accounting Theory*, McGraw-Hill Book Company, Sydney.

3. Посилання на розділ у редагованій книзі:

Автори (рік), Назва глави, In: Редактори, *Назва книги (курсивом)*, Видавництво, Місто, сторінки.

Приклад:

Coffin J.M. (1999), Molecular biology of HIV, In: Crandell K.A. ed., *The Evolution of HIV*, Johns Hopkins Press, Baltimore, pp. 3–40.

Fordyce F.M. (2013), Selenium deficiency and toxicity in the environment. In: Selinus O. (ed.), *Essentials of Medical Geology*, pp. 375–416, Springer, DOI: 10.1007/978-94-007-4375-5_16

4. Тези доповідей конференції:

Arych M. (2018), Insurance's impact on food safety and food security, *Resource and Energy Saving Technologies of Production and Packing of Food Products as the Main Fundamentals of Their Competitiveness: Proceedings of the 7th International Specialized Scientific and Practical Conference, September 13, 2018,* NUFT, Kyiv, pp. 52–57.

5. Посилання на електронний ресурс:

Виконується аналогічно посиланню на книгу або статтю. Після оформлення даних про публікацію пишуться слова **Available at:** та вказується електронна адреса.

Приклад:

Cheung T. (2011), *World's 50 most delicious drinks*, Available at: http://travel.cnn.com/explorations/drink/worlds–50-most-delicious-drinks–883542

Список літератури оформлюється лише латиницею. Елементи списку українською та російською мовою потрібно транслітерувати. Для транслітерації з української мови використовується паспортний стандарт.

Зручний сайт для транслітерації з української мови: http://translit.kh.ua/#lat/passport

Стаття надсилається за електронною адресою: ufj_nuft@meta.ua

УДК 663/664

Ukrainian Food Journal публікує оригінальні наукові статті, короткі повідомлення, оглядові статті, новини та огляди літератури.

Тематика публікацій в Ukrainian Food Journal:

Харчова інженерія	Процеси та обладнання
Харчова хімія	Нанотехнології
Мікробіологія	Економіка та управління
Фізичні властивості харчових продуктів	Автоматизація процесів
Якість та безпека харчових продуктів	Упаковка для харчових продуктів

Періодичність виходу журналу 4 номери на рік.

Результати досліджень, представлені в журналі, повинні бути новими, мати чіткий зв'язок з харчовою наукою і представляти інтерес для міжнародного наукового співтовариства.

Ukrainian Food Journal індексується наукометричними базами:

– Index Copernicus (2012)
– EBSCO (2013)
– Google Scholar (2013)
– UlrichsWeb (2013)
– CABI full text (2014)
– Online Library of University of Southern Denmark (2014)
– Directory of Open Access scholarly Resources (ROAD) (2014)
– European Reference Index for the Humanities and the Social Sciences (ERIH PLUS) (2014)
– Directory of Open Access Journals (DOAJ) (2015)
– InfoBase Index (2015)
– Chemical Abstracts Service Source Index (CASSI) (2016)
– FSTA (Food Science and Technology Abstracts) (2018)
– Web of Science (Emerging Sourses Citaton Index) (2018)
– Scopus (2022)

Рецензія рукопису статті. Матеріали, представлені для публікування в «Ukrainian Food Journal», проходять «Подвійне сліпе рецензування» двома вченими, призначеними редакційною колегією: один є членом редколегії і один незалежний учений.

Авторське право. Автори статей гарантують, що робота не є порушенням будь-яких авторських прав, та відшкодовують видавцю порушення даної гарантії. Опубліковані матеріали є правовою власністю видавця «**Ukrainian Food Journal**», якщо не узгоджено інше.

Детальна інформація про Журнал, інструкції авторам, приклади оформлення статті та анотацій розміщені на сайті:

http://ufj.nuft.edu.ua

Редакційна колегія

Наукове видання

Ukrainian Food Journal

Volume 11, Issue 4
2022

Том 11, № 4
2022

Підп. до друку 28.02.2023 р. Формат 70х100/16.
Обл.-вид. арк. 12.71. Ум. друк. арк. 12.73.
Гарнітура Times New Roman. Друк офсетний.
Наклад 100 прим. Вид. № 24н/22.

НУХТ. 01601 Київ–33, вул. Володимирська, 68

Свідоцтво про державну реєстрацію
друкованого засобу масової інформації
КВ 18964–7754Р
видане 26 березня 2012 року.