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THE USE OF CEDAR AND WALNUT MEAL IN THE TECHNOLOGY OF BUTTER BISCUITS

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T 44 **Shydakova-Kameniuka O. G.**
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The monograph summarizes the results of research aimed at scientifically substantiating the use of cedar and walnut meal in the technology of sandy butter biscuits with partial replacement of solid fat with liquid oil. This allows avoiding the additional use of synthetic emulsifiers to stabilize the emulsion semi-finished product and obtaining butter biscuits with high nutritional and biological value.

The publication is intended for teachers, postgraduates, and students specializing in "Food Technologies." It can also be used by students of related specialties and professionals in the food industry..

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CONTENT

List of conventional abbreviations

TIFA – trans isomers of fatty acids;
STG – solid triglycerides;
PUFA – polyunsaturated fatty acids;
CM – dietary supplement "Cedar meal"
WM – dietary supplement "Walnut meal";
WHC – water-holding capacity;
AEF – ability to emulsify fats;
FHC – fat holding capacity;
DTA – differential curves of thermal effects/differential thermal analysis;
TG – curves of changes in mass of samples/ thermogravimetric analysis.

INTRODUCTION

In the contemporary diet, there is a declining proportion of biologically valuable products, contributing to an elevated risk of various foodborne diseases. Recognizing this, the innovative trends in the global food industry prioritize the creation of health-oriented products. Achieving this goal involves the incorporation of non-traditional ingredients rich in substances beneficial for the human body.

Statistical data indicates a rising trend in the production volume of butter cookies in Europe. Considering the non-compliance of this product with healthy nutrition requirements, there is potential for technological modifications to enhance its nutrient composition. A crucial step in shortbread cookie technology involves the production of an emulsion semi-finished product. Typically, fat bases like palm oil, margarine, shortenings, and confectionery fats, containing high levels of saturated fats or trans isomers of fatty acids, are used. These substances pose potential health risks.

Therefore, exploring alternatives, such as the full or partial replacement of these fats with liquid oils characterized by higher levels of polyunsaturated fatty acids, fat-soluble vitamins, and the absence of trans isomers of fatty acids, becomes imperative. However, the utilization of liquid oils in shortbread cookie technology is hindered by specific technological challenges. Liquid oils tend to form unstable emulsions, easily separate during baking and storage, adversely affecting product quality.

To address this, stabilizing emulsions with liquid oils requires the additional use of emulsifiers, such as protein substances, modified starches, gums, food fibers, and other high-molecular compounds. Alternatively, the use of natural raw materials containing these substances is a viable option.

This approach ensures the necessary structural and mechanical properties of the dough and guarantees high-quality indicators for the finished cookies. Plant-based supplements emerge as promising candidates due to their inherent complex of nutrients, including vitamins, minerals, phenolic compounds, and dietary fibers, presented in an accessible and digestible form.

Cedar and walnut meal, finely dispersed additives derived as by-products from the corresponding oil production, contain a significant number of substances with functional and technological properties. These substances serve as concentrates of vital nutrients for humans. Currently, nut meal finds application in confectionery production either as a substitute for nut raw materials or as a partial replacement for flour to enhance nutritional and biological value.

This monograph consolidates the outcomes of research efforts aimed at scientifically justifying the use of cedar and walnut meal in shortbread cookie technology. The focus is on partial replacement of solid fat with liquid oil, thereby eliminating the need for additional synthetic emulsifiers to stabilize emulsion semi-finished products. The ultimate goal is to produce cookies with elevated nutritional and biological value.

The monograph draws extensively from the dissertation work of Novik G., conducted under the supervision of PhD, Associate Professor Shidakova-Kamenyuka O.

The presented materials are a translation of the authors' monograph with [Шидакова-Каменюка О. Г., Новік Г. В., Болховітіна О. І. Технологія здобного печива з використанням рідких олій та горіхових шротів : Монографія. Дніпро: ЛІРА, 2023. 193 с.] additions.

CHAPTER 1.
The relevance of the use of nut meal in the technology of butter cookies

1.1. Modern trends in improving the nutritional composition of cookies

In the present era, notable imbalances in the population's diet structure have been identified, primarily stemming from a reduction in the consumption of food products rich in physiologically useful substances, such as meat, dairy products, vegetables, fruits, and berries. This deficiency in physiologically valuable nutrients is associated with decreased non-specific resistance to environmental factors, compromising the adaptive potential of individuals and posing a risk for various micronutrient deficiency diseases and food-related conditions (e.g., atherosclerosis, hypertension, hyperlipidemia, obesity, diabetes, osteoporosis, gout, etc.). Additionally, it hampers the physical and neuropsychological development of children and leads to diminished work capacity. Consequently, there has been a surge in the prevalence of excess weight and cardiovascular diseases, attributed to metabolic disruptions, ultimately resulting in a significant decrease in life expectancy, notably by almost 30% in recent years.

The situation is further exacerbated by deteriorating ecological conditions, leading to soil contamination with toxic substances, imbalances in water microelement composition, and alterations in the biogenic element levels and toxic element content in food products.

To address identified nutritional deficiencies and enhance the adaptability of the human body to negative environmental factors, a viable solution is the enrichment of daily food products with essential substances. In light of this, consumers increasingly favor functional products, which are enriched food items designed for systematic consumption across all age groups of the healthy population. These products exert a pronounced physiological effect, regulating specific bodily processes, are crafted from natural ingredients, and mitigate the risk of diseases.

While traditional food products prioritize nutritional value and taste, functional products encompass an additional physiological dimension, positively influencing one or more bodily functions, aiding in disease prevention, and contributing to overall health [1, 2].

The experience of highly developed countries underscores the effectiveness and economic viability of developing functional food products to rectify dietary issues. This approach encourages food industry enterprises to prioritize the production of safe and healthy products. Achieving this goal involves modifying traditional technologies by incorporating new raw ingredients rich in physiologically useful nutrients, thereby enriching food products. The convenience of using such products lies in their seamless integration into existing dietary habits.

In this context, enriching high-demand products becomes particularly promising. Notably, the confectionery industry, a significant segment of Eastern Europe's market, offers around two thousand products, with cookies and wafers occupying a substantial share. Following a dip in production in 2014–2015, the market for cookies and wafers witnessed a growth of 5.8% in 2017, a trend that persists to date. The stability of this confectionery sector is attributed to a diverse product range and minimal price fluctuations, supporting its sales ratings [4]. Traditional cookie recipes often feature high-calorie raw materials with low biological value, such as high-grade flour, fats (margarine, butter, confectionery fats, shortenings, etc.), and sugar. These cookies, rich in carbohydrates and fats, fall short of being considered "healthy food." Consequently, cookies emerge as a promising candidate for technological modification to enhance their nutrient composition.

We have organized modern approaches proposed by scientists to address the challenge of enriching cookies with physiologically useful substances. This categorization has led to the identification of two primary directions: the incorporation of synthetic drugs into the product formulation and the utilization of natural biologically valuable raw materials and their processed products (Table 1.1).

Enriching cookies with artificially synthesized drugs involves integrating vitamin and mineral premixes of industrial production and specific vitamin and mineral supplements into the technology [6]. The advantage of these additives lies in their availability in trade networks, ease of technological use (simple dosing), and the ability to regulate nutrient content in the final product [7].

Table 1.1 – **Non-traditional additives to improve the nutritional composition of cookies**

Origin of additives	Types of additives	Advantages	Disadvantages
1	*2*	*3*	*4*
synthesized preparations (vitamins, minerals and their complexes)	*Monopreparations*	- availability in trade networks; - produce-ability; - composition stability	- limited enrichment; - strict compliance with dosage recommendations; - necessity to take into account the possible interaction with raw materials; - low bioavailability
	Polypreparations		

Continuation of Table 1.1

1	*2*	*3*	*4*
natural raw materials and products of their processing	*animal origin* (products of processing of edible bone and blood of slaughtered animals, secondary dairy raw materials, etc)	- high content of biologically valuable proteins, certain mineral substances (calcium, iron, etc.); - presence of certain functional technological properties	- microbiological instability; - necessity of special storage conditions; - lack of dietary fiber and some minor nutritional components (phenolic substances, polyunsaturated fats, organic acids, etc.)
	plant origin (mashed potatoes, juices, powders, non-traditional flour, etc. products from oil, fruit and berry, vegetable, nut, grain, wild plants and other raw materials)	- presence of physiologically significant nutrients in the form of a natural complex with a high level of bioavailability; - relatively low cost; - no special storage requirements; - presence of functional technological properties	- dependence of the chemical composition on many factors (species or variety, region of raw material cultivation, weather conditions, processing methods, etc.); - lack of commercial forms of some supplements

Enrichment of mass consumption products with vitamins and minerals (technological modification) involves the direct addition of vitamins or their mixtures to a food product during the production process, with mandatory labeling and indication of the micronutrient dose introduced into the product [8]. Two main types of enrichment of food products with vitamins and minerals are depicted in Fig. 1.1.

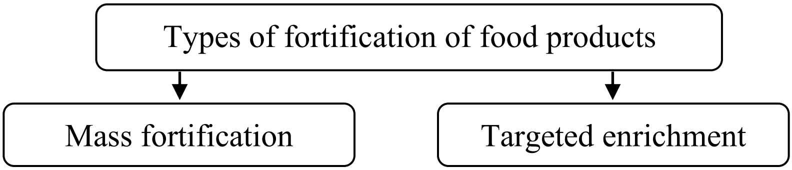


Fig. 1.1. Types of enrichment of food products with vitamins and minerals

The enrichment of mass consumption products with vitamins and minerals involves the fortification of food items such as bread, bakery products, dairy products, grain products (cereals, muesli, cereals), juices, nectars, drinks, and iodized salt. These products, consumed daily by all segments of the population over the age of 3, undergo mass fortification. On the other hand, targeted enrichment is aimed at specific categories of the population. While fortification of mass consumption products is typically mandatory and established by law, targeted fortification can be either mandatory or voluntary, depending on the specific issue to be addressed [8].

Voluntary fortification, often termed "industry-driven fortification" or "market-driven fortification," is prevalent in industrialized countries and is initiated by producers. It is regulated by state documents. Unfortunately, voluntary fortification, where vitamins and minerals are added at the discretion of food manufacturers, is sometimes carried out primarily for marketing purposes [8].

Unlike some staple food items included in the "consumer basket," there are no specific daily use recommendations for cookies. Consequently, the use of synthetic drugs for cookie enrichment may lead to their excessive intake into the human body [9].

Moreover, there are considerations regarding the potential chemical interaction of such preparations with the substances of enriched products, and their alterations under the influence of the technological parameters of cookie production, particularly at high baking temperatures. This form of enrichment tends to be narrowly focused, introducing a specific substance or a complex of certain substances without the possibility of extracting or replacing recipe components with low biological value, such as margarine, sugar, and wheat flour. Some scientists also argue that synthetic drugs are less effectively absorbed by the human body compared to natural alternatives [10].

In the contemporary landscape, there is an increasing emphasis on enriching the nutritional composition of cookies using natural raw materials [11, 12] (see Fig. 1.2).

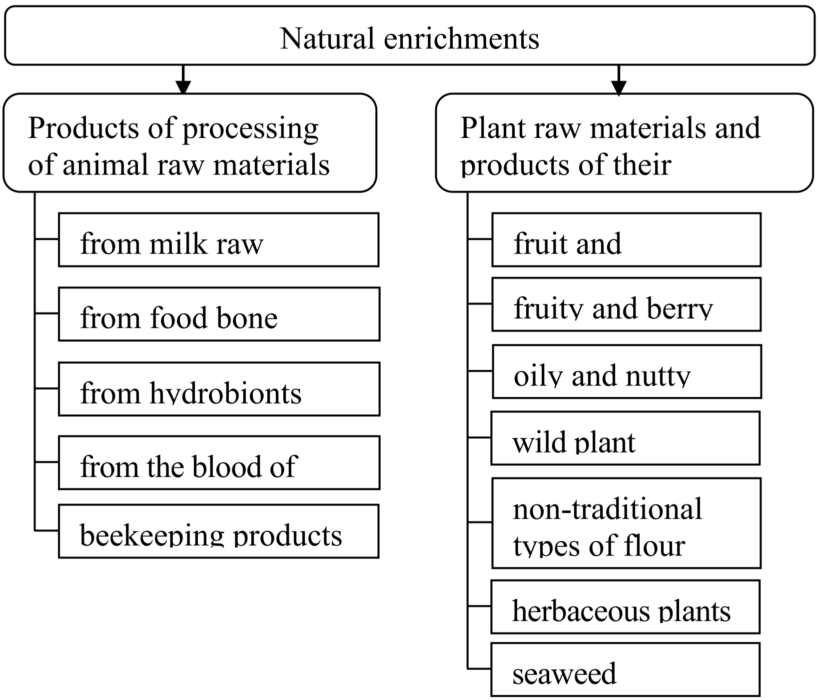


Fig. 1.2. The main types of raw materials of natural origin used to improve the nutritional composition of cookies

Compared to synthetic drugs, natural raw materials have significant advantages, particularly containing a natural complex of biologically active substances, macro- and micronutrients in the most accessible and digestible form. Various proposals suggest the utilization of animal raw material processing products in cookie technology, such as hydrobionts [13, 14], edible bone [15], blood of slaughtered animals [16], beekeeping products [17], and milk whey [18].

For instance, work [14] suggests the use of fish bone powder obtained from Nile tilapia (12% of the weight of wheat flour) in cookie technology. Consumption of 100 g of such cookies provides 39%, 34%, 62%, and 57% of the recommended daily allowance of protein, calcium, phosphorus, and iron, respectively. The authors [15] substantiated the feasibility of using semi-finished bone food (10% of the total weight of raw materials) obtained from edible bone by hydrothermal treatment at high pressure with subsequent grinding during the production of shortbread cookies. The introduction of the additive will significantly enrich the cookies with organic calcium compounds and reduce the prescription dosage of fat.

There are proposals for using beekeeping products (flower pollen) in the amount of 6–7% of the flour mass in cookie technology [17]. The use of such raw materials not only enriches products with biologically valuable substances but also positively affects the stability of their quality during storage.

The disadvantage of the above methods of enriching cookies is the high cost of some additives (byproducts), microbiological instability (raw materials based on edible bone or blood of slaughtered animals), the need to ensure certain storage and transportation conditions, and the absence or low content of dietary fibers and some minor nutritional components (polyunsaturated fats, organic acids, polyphenols, etc.).

Considering this, it is more promising to use vegetable raw materials and products of their processing to improve the nutritional composition of butter cookies. The presence of dietary fibers, organic acids, phenolic compounds, vitamins, and minerals in the specified raw material not only gives it high biological value but also causes it to exhibit high functional and technological properties, providing an opportunity to influence the course of technological processes, the quality of semi-finished and finished products [19, 20].

Plant raw materials can be added to cookie technology in the form of pastes, purees, juices, powders (including non-traditional types of flour), or their combinations. Research is actively being conducted to study the possibility of using vegetable raw materials in cookie technology.

Carrots, beets, and pumpkins are most often recommended to be added to cookies in the form of mashed. There are proposals to use such mashed in shortbread technology with a reduction in the recipe amount of sugar and fat (in the amount of 10–15%) [21] or in the technology of long dough cookies instead of water [22]. Kirpichenkova O. and Obolkin V. recommend adding hydrolyzed carrot puree (up to 10% of the mass of the mélange) to shortbread biscuits [23]. Zadorozhnya O., Gavrish A., and Dotsenko V. suggest using raw or cooked carrot puree (19% of the mass of the dough) and a carotene-containing fortifier "Carrot honey" (11% of the mass of the dough) [24]. Carrot (9% of the mass of the finished product) and pumpkin (up to 40% of the mass of flour) puree are also added during the production of oatmeal cookies [25, 26].

Suggestions are also provided for the use of puree made from Chaenomeles (10% of the flour mass) during the production of shortbread cookies [27]. The use of vegetable puree in cookie technology helps increase the density of the emulsion, enhance its stability, and improve the rheological characteristics of the emulsion and cookie dough. Additionally, the structural and mechanical properties of the product improve (wetting, friability, porosity), cookies acquire a pleasant taste and aroma, go stale more slowly during storage, and are enriched with biologically active substances.

The disadvantage of herbal puree supplements is the difficulty of their storage, dosing, and transportation. Also, such additives have not become widespread in the market, and confectionery companies do not always have the possibility of their production. In addition, puree is characterized by high moisture, and adding additional moisture to some types of cookies, particularly shortbread, is undesirable. With this in mind, more attention is being paid today to the introduction of supplements in powder form. The advantages of powders over purees, extracts, juices, etc., consist in the ease of their transportation, ease of storage, and dosing conditions, etc. Additionally, a significant amount of powdered raw materials is a secondary product of the main production. As a result, biscuit manufacturers can receive ready-made powder with appropriate quality certificates, and there is no need to change the hardware design of the process. Due to low humidity, powdered products contain a higher concentration of biologically active compounds.

The use of non-traditional types of flour, such as corn, amaranth, soybean, triticale, chickpea, lupine, etc., has become widespread in cookie technology. An important feature of these types of flour compared to wheat flour is the absence of gluten-forming proteins in their composition [28]. This is important for the technologies of some types of cookies that require the use of flour with a low gluten content.

The possibility of completely replacing wheat flour with corn [29], chickpea [30], or their mixture (1 : 1) [31] in the shortbread recipe was considered, allowing the use of such products in gluten-free diets. Corn and chickpea flour help normalize cholesterol and blood sugar levels, improve bowel function, and have a number of other beneficial properties. The new products have a pleasant color, a harmonious taste and aroma, a delicate, crumbly structure, and are characterized by an increase in the content of β-carotene, vitamins A, B1, and B2, minerals (potassium, phosphorus, calcium, sodium, magnesium, iron), and dietary fibers.

It is recommended to use amaranth, soy, or lupine flour in gluten-free cookie technologies. Additions are made instead of wheat flour in the form of a mixture with potato and corn starch. The share of non-traditional flour in the mixture is 40%. The use of the specified mixture in the technology of shortbread cookies allows you to reduce the consumption of fat in the recipe: in the case of using amaranth flour – by 8%, lupine flour – by 12%, soy flour – by 16%. Additives also help to slow down the aging process of products and inhibit the oxidation of fats during storage [32]. To obtain gluten-free products, it is also proposed to completely replace wheat flour in the recipe for sugar cookies with triticale flour [33] or a mixture of rice and buckwheat flour (60 : 40 or 50 : 50) [34], and in the recipe for short-cut butter cookies with a mixture of buckwheat flour and quinoa (70 : 30) [35].

The authors [36] proposed a technology for oat cookies, which includes first-grade wheat flour, triticale flour, oat flour, and chickpea sprout flour in a ratio of 25.5–30.0 : 38.26–50.50 : 1.5–7.0. The finished products are characterized by a higher content of protein, starch polysaccharides, and an improved micronutrient composition.

The use of buckwheat [37] or amaranth [38] flour in the technology of sugar cookies will enrich the product with physiologically useful nutrients, increase the plastic properties of the dough, and improve the structural and mechanical characteristics of the finished product. There are recommendations for the use of amaranth flour also in the technology of butter cookies (8% of the mass of flour) [39].

Technologies for butter cookies with the addition of rye flour (50% by weight of wheat), triticale flour (30% by weight of wheat), or their mixture (the ratio of wheat, rye, and triticale flour is 40 : 30 : 30) are proposed [40].

The possibility of adding oat malt flour to butter cookies in the amount of 30% of the total mass of raw materials has been determined. The presence of active proteolytic enzymes in the specified additive promotes the hydrolysis of dough proteins, as a result of which plasticization of the dough semi-finished product occurs, allowing a reduction in the recipe consumption of fat by 15%. Also, malt flour contributes to the accumulation of mono- and disaccharides, which will reduce the sugar content by 25% [41].

Scientists from Kazakhstan have provided proposals for replacing 10% of high-grade wheat flour in the shortbread biscuit recipe with a mixture (1 : 1) of sorghum and rapeseed flour [42]. The possibility of using millet flour in the technology of sugar (25% of the mass of wheat flour) and long-lasting (10% of the mass of wheat flour) cookies was considered [43].

Improving the consumer properties of butter cookies (biological value, organoleptic and structural-mechanical characteristics) can be achieved in the case of using spelled flour (20% of the weight of wheat) mixed with pumpkin powder (4% of the weight of wheat flour) [44]. In work [45], it is proposed to replace 50% of wheat flour with spelled flour in the shortbread recipe, and to improve the taste characteristics and enrich it with carotene, add orange peel and chopped fresh carrots.

A recipe for butter cookies has been developed with the replacement of 15% of wheat flour with pea flour. The introduction of pea flour allows you to enrich the cookies with biologically valuable protein, vitamins (A, B1, B2, PP, β-carotene), minerals (calcium, magnesium, phosphorus, iron), and has a positive effect on the stability of the quality indicators of the product during storage [46]. Improving the protein composition of cookies is possible due to the use of 15-20% flour from beans [47].

The use of pumpkin seed flour in the technology of shortbread cookies allows reducing the recipe costs of flour by 26%, butter by 13%, and sugar by 9%. At the same time, there is an increase in the plastic properties of the sand dough and an increase in the friability of the finished products. Additives are added at the stage of obtaining an emulsion [48]. The authors [49] recommended the combined use of pumpkin seed flour (20% of the weight of wheat flour) and citrus or apple pectin (1.4% of the weight of wheat flour) during the production of shortbread cookies, ensuring improved preservation of organoleptic and structural-mechanical characteristics of finished products in the storage process, and, as a result, extending the duration of product storage.

Bachynska J. proposed using pumpkin seed meal in the technology of sugar cookies (in the amount of 2.76% of the mass of flour). The meal contains more than 50 macro- and microelements, has bactericidal, anti-inflammatory, anti-parasitic, anti-allergic, and anti-tumor properties [50].

Recipes for buttery cookies with the addition of carrot powder ("Lakomka"), mountain ash powder ("Original"), and pieces of dried carrot ("Vesnushka") have been developed [51].

It is recommended to use Jerusalem artichoke powder separately or in a complex with amaranth flour (10% of the weight of wheat flour) [52], or in a mixture with cherry berry flour with the removal of part of the sugar from the recipe – the ratio of wheat flour : cherry berry flour : Jerusalem artichoke powder is 75 : 5 : 20 [53]. The complete removal of sugar from the shortbread recipe is possible if Jerusalem artichoke powder and stevia powder are used in its recipe in the amount of 9.09 and 0.71% of the total mass of raw materials, respectively [54]. In the recipe for slow-cooking cookies, it is recommended to use 7% of the flour mass of Jerusalem artichoke powder with the replacement of sugar with fructose. The introduction of these additives has a positive effect on the quality of emulsion and dough [55, 56]. There are recommendations for the use of water Jerusalem artichoke extract and dietary fiber from solid insoluble sediment in the amount of 6% of the mass of dry substances of the finished product in sugar cookie technology. The dosage of Jerusalem artichoke extract was carried out at the stage of preparing the emulsion instead of the prescribed amount of water, and the powder of dietary fibers – at the stage of kneading the dough [57]. Products with Jerusalem artichoke powder can be included in the diets of people with carbohydrate metabolism disorders [58].

Proposals have been made to replace 3% of wheat flour in the shortbread biscuit recipe with chicory powder, which helps to improve the structure of the products and extend the shelf life [59].

The source of easily digestible protein, dietary fiber, polyunsaturated fats, vitamins of group B, micro- and trace elements are oil crops (kernel, seeds) and their processing products (pastes, oils, meal, cakes, groats, etc.).

Soy products are widely used in the production of cookies. It is proposed to use soy okara (20% of the dough mass with reduced egg and flour content) [60], soy paste (30% of the egg-fat mixture mass) [61] or meal (20% of the dough mass) in the technology of shortbread products with reduced consumption of eggs and fat) [62]. Soy grits and full-fat soy flour are recommended to be used in cookie technologies in the amount of 8–10% of the weight of the semi-finished product [63]. The use of soybean processing products has a positive effect on the rheological properties of the dough, allows you to significantly reduce the cost of products, and extend their shelf life.

Recommendations are provided for the use of a composition of soybean, sunflower, and thistle meal in the ratio of 3 : 4 : 3 in shortbread technology. The introduction of the composite mixture is carried out in the amount of 20% of the mass of the dough at the stage of kneading [64].

To enrich cookies with protein, polyunsaturated fatty acids, and vitamin E, it is recommended to use sunflower seed kernels in their entirety (10% of the total mass of the dough) [65] or in the form of a paste of fried and raw kernels (10% of the mass of butter) [66]. There are proposals to add whole or crushed flax seeds to shortbread cookies in the amount of 10 and 7.5% of the dough weight, respectively [67]. The use of 3.5% sesame seeds gives cookies a golden color with a delicate red-orange shade and a crispy structure [68]. Adding 25% rapeseed powder to the flour mass during the production of shortbread cookies allows for a 15% reduction in butter recipe costs [69].

It is recommended to replace 20% of the flour with crushed milk thistle fruits to give shortbread hepatoprotective properties at the dough kneading stage [70].

In order to enrich cookies, it is recommended to use products of processing of fruit and berry and wild plant raw materials (fruits, berries, herbaceous plants, etc.).

Proposals for the use of banana and pineapple powders [71], persimmon powder in shortbread technology are provided [72]. The introduction of fruit powders is carried out in the amount of 10% of the weight of wheat flour with a decrease in the recipe costs of sugar, fat, and eggs, which helps to reduce the energy value of the products. It is proposed to introduce powders from apples, oranges, apricots, beets, carrots, obtained by the method of cryogenic freezing, into the specified technology. Additions are made with the replacement of part of the sugar in the amount of 10–20% of the mass of flour [73, 74]. It is prospective to use secondary products of the wine and beer industries in the cookie technology. There are proposals for the use of dietary fibers from grape pomace (10% of the flour mass at the stage of dough kneading) [75], grape pomace powders (5% of the flour mass) [76 – 78], grape seed powder (15% of the mass of flour) [79]. Recommendations are given for replacing 15% of wheat flour in the recipe for butter cookies [80] and 10% in the recipe for sugar cookies with beer groats flour [81]. It is also suggested to use 5% flour from beer groats and 3% flour from sunflower cake during the production of sugar cookies. [82]. Cookies using grape processing products are characterized by an extended shelf life (due to the presence of a high amount of polyphenols), have a chocolate color and taste. Cookies using beer groats flour acquire a pleasant taste of oat cookies and a brown color.

Domestic and foreign scientists recommend adding 5% to the flour mass of processed hawthorn products (pulp with skin, seeds, and fruits) [83], black rowan powder [84], blackberry processed products [85], from sea buckthorn [86], from squeezes of blueberry berries [87]. The introduction of additives is carried out at the stage of emulsion preparation. At the same time, the research samples have improved consumer properties, including high sensory, physical and chemical, and structural-mechanical quality indicators.

It is possible to replace 15% of wheat flour in the shortbread recipe with blackcurrant cake powder [88]. This will give cookies original taste properties and significantly enrich them not only with vitamins and pectin substances but also with phenolic compounds of anthocyanin nature [89], which are antioxidants and slow down the oxidation of cookie fats during storage.

In the recipe for long-lasting cookies, it is recommended to replace 15% of the flour with gooseberry fruit powder [90], and in the long-lasting recipe – 6% with rosehip fruit powder [91].

In work [92], the expediency of using products of processing of wild raw materials – frozen dogwood fruits (6% of the flour mass) or bird-cherry powder (8% of the flour mass) in the technology of sand-set butter cookies was established. The resulting products have an original harmonious combination of buttery and berry taste and smell, with good physical and chemical quality indicators and an increased content of β-carotene, vitamins C, PP, and B6. In the technology of slow-cooking cookies, cherry powder is suggested to be added in the amount of 1% of the mass of flour [93], and in the technology of sugar – in the amount of up to 8% of the mass of flour [94]. The authors [95] also provided proposals for the use of crushed lingonberry berries (10% by weight of flour) during the production of sugar and shortbread cookies, which ensures an increase in the content of dietary fibers (by 38...40%), minerals (potassium, calcium, magnesium and phosphorus) and vitamins B1 and PP.

There are recommendations for replacing 5% of wheat flour in the shortbread recipe with fern powder [96]. Alferov D. developed a recipe for butter cookies with the addition of 3% of the total amount of nettle powder [97]. The indicated herbal powders are added at the stage of dough kneading together with flour.

The use of algae processing products in cookie technology is promising. The peculiarity of the chemical composition of such raw materials is the high content of iodine in a biologically available form and the presence of alginates – substances that have high technological value (capable of forming stable structured systems) and have therapeutic and preventive properties (they bind and remove salts of heavy metals, radionuclides from the body).

It is recommended to use kelp powder in the technology of sugar (2% of the mass of wheat flour) and oat (15% of the mass of flour) cookies, and powder of fucus algae – in the technology of shortbread cookies (7% of the mass of wheat flour) [98 – 100]. In work [101], proposals were made for the use of Alaria esculenta and Palmaria stenogona algae powders in the amount of 1.0 to 8.0% of the mass of the finished product in the technology of shortbread cookies. Algae powders are recommended to be added at the stage of dough kneading together with flour. There is an increase in the humidity and wetting of the products, an increase in the content of insoluble polysaccharides, iodine, and some other minerals (iron, potassium, calcium, magnesium) in them.

Summarizing the analysis of information sources allows us to note that the use of plant raw materials and products of their processing in cookie technology allows solving several issues at the same time. First, complex enrichment with physiologically useful nutrients in a bioavailable form is provided. Secondly, certain features of the chemical composition of such raw materials cause them to exhibit functional and technological properties (water-absorbing, fat-retaining, foam-forming, etc.). This has a positive effect on the structural and mechanical characteristics of semi-finished products and finished cookies, allows you to adjust the recipe composition of products (in particular, reduce the content of raw materials with a high cost or with low biological value), inhibit staleness (additives containing pectin, alginates and other non-starch polysaccharides), prevent oxidation of the lipid complex during storage (additives with a high content of polyphenolic compounds), and solve a number of other technological tasks.

1.2. Peculiarities of the use of fatty raw materials in the technologies of butter shortbread cookies

Depending on the composition of the recipe and the method of production, there are sugar, long-lasting, butter (sandwich, batter, nut, puff, crackers), oat cookies, and cookies for special dietary purposes. A feature of shortbread cookies is the highest, compared to others, content of the fat component – 30…35%. As a result, fats play an important role in shaping its quality. So, for example, with an excess of fat in the dough, it can form a continuous phase, which gives the finished cookie a soft and delicate texture, while at low concentrations, the fat is dispersed, ensuring a strong and hard structure of the cookie.

During dough kneading, fat molecules interact with flour proteins at the site of non-polar functional groups, forming a film around protein micelles that prevents their contact with water. Fats are also adsorbed on the surface of starch grains. As a result, the swelling of flour particles is limited, the content of the liquid phase in the dough increases, leading to a weakening of the bonds between the components of the solid phase. As a result, the dough becomes more plastic, and the finished products have the necessary crumbly structure [102, 103]. An important function of fats in shortbread dough is the ability to cover small air bubbles, preventing them from breaking and merging into larger ones, thereby increasing the stability of the foam emulsion system. This interaction of fats with the gas phase is more effectively expressed in fats with a crystalline structure [104].

It is the fat crystals that are largely responsible for stabilizing the structure of the whipped emulsion [105], since during emulsification, they ensure the capture of air to the whipped semi-finished product and are held on the bubbles due to capillary forces [106, 107]. This ensures the uniformity of the distribution of the gas phase in the emulsion and dough semi-finished products and the formation of a porous and crumbly structure of the finished products [108].

Fats for the production of cookies should be plastic. Plasticity characterizes the ability of fat to change shape under the influence of mechanical influence without breaking integrity, that is, the ability to retain its shape after stress is removed. Plasticity is determined by the ratio of solid and liquid phases in a certain temperature range. The best plasticity is characteristic of fats in which the content of solid triglycerides (STG) is 15…30% (and according to some data – 15...20% [109]) and remains unchanged in the temperature range of 10...30ºC. Therefore, such fats are characterized by a wide range of melting temperatures, at which it retains its plastic properties [110, 113].

The technological properties of fat largely depend on the shape of its solid-phase crystals. This membrane allows a large number of crystals of the solid phase of the fat product to attach to the air bubbles. During baking, the fat crystals melt, and the protein matrix unites with the surface of the bubbles during their expansion, increasing the resistance to destruction. Fat, in the process of melting, acquires a liquid consistency, while air bubbles tend to float up and out of the dough. The longer the air bubbles stay in the dough, the more porous the product will be. For the effective effect of fats, the uniform distribution of their crystals is important, and to achieve such a distribution, a liquid part of the fat is necessary [109].

Fats of a solid consistency are characterized by the ability to crystallize into fine crystals – butter, natural solid vegetable fats (palm), modified solid oils (margarine, confectionery fats, shortenings, etc.).

In Table 1.2, a description of some types of fats for making butter cookies, which are produced in Eastern Europe, is given.

Table 1.2 – **Characteristics of some types of fats for the production of butter cookies**

Name	Mass fraction of fat, %	Melting tempe-rature, °C	content of STG at the temperature of 20°C, %	Producers
Butter extra	80…85.0	32…35	20…24	Different producers [112]
Butter peasant	72.5…79.9	32…35	20…24	
Solid natural vegetable fats				
Palm oil	99.8…99.9	33…39	22…31	"Delta Wilmar CIS" LLC [113, 114]
Modified hardened vegetable oils				
Margarine table "Milk flavor"	82	32…36	18…26	"Delta Wilmar CIS" LLC [115]
Margarine table 82%	82	27…38	17…28	"Delta Wilmar CIS" LLC [115]
		34…36	18…24	Holding «Agrarian food technologies» [116]
Margarine table "Sonyachnyy"	72	32…35	20…24	«Delta Wilmar CIS» LLC [115]
Margarine table "Stolychnyy"	60	32…35	18…24	«Delta Wilmar CIS» LLC [115]
Margarine 30-38	80	34…36	18…24	Holding «Agrarian food technologies» [116]
Margarine 32-38	72	34…36	18…24	
Vegetable fat "Universal"	99.7	34…36	32…34	Trademark «Schedro»[117]
Bakefat 02	99.7	34.0…36.0	18…24	Holding «Agrarian food technologies» [118]
Bakefat 05	99.7	20.0…26.0	22…26	
Shortening	99.7	34.0…38.0	20…26	
Universal shortening	99.7	32…36	18…30	«Delta Wilmar CIS» LLC [119]
Confectionery fat «SANIA»	99.7	32…37	22…31	«Delta Wilmar CIS» LLC [119]
Confectionery fat "Shortening 2"	99.8	27…33	16…26	ViOil Industrial Group [120]

Butter has good melting characteristics, a pleasant taste and aroma, as well as technological properties necessary for obtaining high-quality cookies. This type of fat is characterized by high elastic-plastic properties, which are due to the heterogeneous composition of its solid phase, turning into a liquid state in a wide temperature range. Butter is usually used when making premium cookies [108]. The limitation of its wide application is the high cost, low microbiological stability, and short storage time of finished cookies based on it.

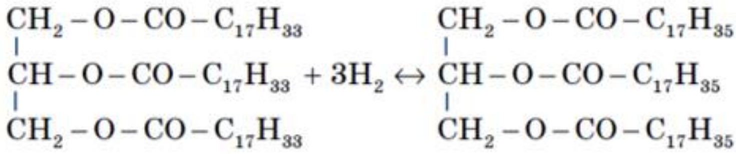
Among solid natural vegetable fats, palm oil is the most widely used in the technology of butter cookies, being as close as possible to butter in terms of physical, chemical, and rheological characteristics. Its use in cookie technology compared to butter is more justified from the point of view of economic feasibility and extension of product storage time. However, usually, in palm oil at a temperature of 20ºC, the STG content is more than 24%, and it also contains a significant amount of symmetrical desaturated and monounsaturated triglycerides (including dipalmitolein). This determines the ability of palm oil to crystallize in various polymorphic states. In this regard, the crystallization of palm oil does not lead to the formation of a sufficiently stable polycrystalline structure, and triglycerides with a low melting point are quickly released in the form of a liquid phase in the event of temperature changes during cookie storage. As a result, migration of fat occurs, and the formation of large fat crystals on the surface of the product, which appear in the form of a whitish spotted film – fatty graying. The inability of palm oil to form a stable crystal lattice gives the finished cookie additional fragility and causes it to crack [108, 111]. Today, in the food industry (including the production of cookies), there is a tendency to limit the use of palm oil, which is due to numerous studies of its negative impact on the human body. It is known that the main fatty acid of palm oil is palmitic acid

(41…50%) [120], the excess of which in the diet contributes to an increase in the blood level of cholesterol, low-density lipoproteins [121], the development of exogenous insulin resistance syndrome, obesity, atherosclerosis, vascular thrombosis, and heart diseases [122 – 127].

Biscuit technology also uses solidified vegetable fats that have acquired a solid consistency as a result of certain modifications – hydrogenation, transesterification, fractionation, etc.

In particular, margarine and shortening are obtained by hydrogenation. The use of margarines in the technology of shortbread cookies has a number of advantages: high aeration capacity, stability of structural and mechanical characteristics, and the presence of emulsifiers in the composition. This allows you to obtain a finely dispersed, lush, air-saturated mass at the emulsification stage [128]. The advantage of shortenings is their high content of dry substances – 99% and higher, and the presence of emulsifiers in the composition. In shortenings, the fat suspension is stable because the solid particles of glycerides and emulsifiers are evenly distributed in the liquid phase of vegetable oils [108]. The presence of emulsifiers ensures high surface activity and good whipping of fatty products with sugar, increases the stability of the emulsion, and prevents the separation of fat from cookies during baking. Compared to margarine, shortenings have a longer shelf life, ensuring an extension of the shelf life of finished products [129].

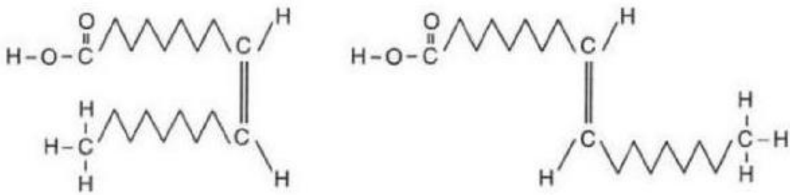
It is known that the essence of the hydrogenation process is the addition of hydrogen to the double bonds of unsaturated fatty acids (Fig. 1.3).



Triolein Tristearin

Fig. 1.3. Scheme of the hydrogenation process

The process is carried out in the presence of a catalyst (nickel, nickel-copper) and at high temperatures (not lower than 180ºC) [130, 131], as a result of which acyl unsaturated fatty acids are isomerized, leading to the accumulation of trans isomers. At the same time, hydrogen atoms are placed on different sides relative to the double bond in the carbon chain, the molecule straightens, and loses the required shape (Fig. 1.4).



a b

Fig. 1.4. Cis- and trans-configuration of fatty acids: a – cis-form; b – trans-form

In the cis-form, the hydrogen atoms are on one side of the double bond, causing the fatty acid molecule to assume a horseshoe shape. In the structure of a trans-fatty acid, the hydrogen atoms are on opposite sides of the double bond, leading the molecule to stretch.

The content of trans-isomers of fatty acids (TIFA) in hydrogenated fats is more than 15%; according to some studies, their amount can reach 40% of the total amount of fatty acids [132, 133]. Currently, the negative impact of trans fatty acid isomers (TIFA) on human health has been proven [134–136]. It has been found that the assimilation of TIFA in the human body is similar to cis isomers; however, they behave differently in biosynthesis processes, particularly competitively interfering with the metabolism of other fatty acids, including essential polyunsaturated ones. TIFA can enter the composition of phospholipids of cell membranes, where, due to the peculiarities of the spatial geometry of the alkyl chain, they tend to pack denser. This leads to a decrease in the fluidity of the lipid layer of the membrane and, as a result, disrupts many metabolic processes, particularly reducing the sensitivity of pancreatic cells to insulin. Therefore, unsaturated fatty acids in the trans-form are unable to perform their functions as part of biological structures. Some studies also suggest that TIFA contribute to a decrease in immunity, the progression of blindness, Alzheimer's disease, atopic dermatitis, obesity, type II diabetes, and cause an increase in blood cholesterol [137].

According to the chemical composition, trans-isomerized fatty acids belong to the unsaturated group, but due to the changed spatial geometric configuration, the trans-isomer acquires the properties of saturated acids. This is expressed in a significant increase in the melting temperature (Table 1.3); the fat becomes solid, significantly complicating its assimilation [138].

It is known that natural fats do not contain fatty acids with a trans-molecular configuration, so the human body has not developed the mechanisms necessary for their assimilation. Since "synthetic" fats have only been in the diet for the past 100 years, our body systems have not evolved to the point where they can control and detoxify these dangerous substances [139].

Table 1.3 – **Dependence of the melting point of some fatty acids on their isomeric form**

Fatty acid	Melting temperature, °C	
	Cis-form	*Trans*-form
Oleic	15	44…45
Linoleic	–5	28…29
Linolenic	–11	29…30

Today, the use of fat products containing TIFA for food purposes is prohibited or restricted in Denmark, Switzerland, Austria, Hungary, Norway, and in some US states. In many countries, manufacturers are required to indicate the content of trans fats on food products [140]. The World Health Organization recommends limiting TIFA consumption to no more than 1% of daily energy needs [141]. Considering this, manufacturers are paying more and more attention to the search for alternative types of fatty products that do not contain TIFA.

In many European countries, transesterification is preferred over hydrogenation to obtain modified fats. The purpose of this process is a directed change in consistency, physical properties (melting point, hardness), and the creation of a stable crystalline structure of fat or a mixture of fats [142]. The use of transesterification makes it possible to obtain plastic mixtures of triglycerides with different consistencies (Fig. 1.5).

The structural components of these mixtures are mixed triglycerides of saturated and non-isomerized unsaturated fatty acids [143]. The desired fatty acid composition of transesterified fat and its properties are determined by the derived ratio of solid and liquid components.

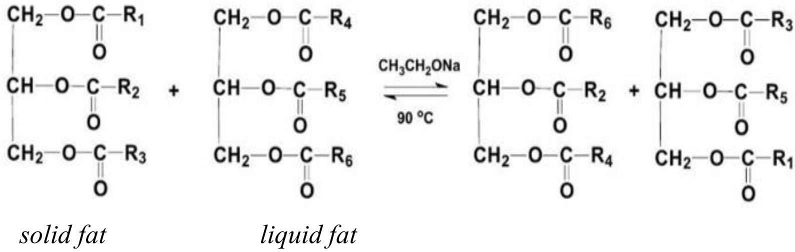


Fig. 1.5. Flow chart of the transesterification process

The transesterification process (chemical or enzymatic) consists of the mutual exchange of two triacylglycerols with fatty acid radicals and is carried out in the presence of special catalysts (of chemical origin or lipase enzyme). The use of catalysts during transesterification contributes to the reduction of the energy barrier for the activation of the relevant processes, allowing the process to be carried out at a relatively low temperature (compared to the hydrogenation process) – 30...100ºC. As a result, isomerization of fatty acids almost does not occur (the content of fatty acids does not exceed 1%), and the fatty acid composition of derived fats does not change [130]. The advantages of chemical transesterification over enzymatic transesterification are that this technology has been used for many years and is fully developed. Also, the periodicity of the process ensures the stability of the physicochemical parameters of the obtained fats and makes it possible to produce batches of the product of different volume and assortment. Disadvantages include the need for post-whitening, which is accompanied by the formation of by-products [144].

Enzymatic transesterification (unlike chemical transesterification) is not accompanied by the formation of by-products. The low reaction rate allows stopping it at any time, enabling the obtaining of the required degree of transesterification for the production of fatty products with a given chemical composition and the required technological properties [145, 146]. However, the enzyme preparations necessary for the course of the specified reaction are not widely produced by the industry; as a result, this technology for obtaining modified fats is not widespread in Eastern Europe.

Recently, the technology of obtaining modified fats by fractionation is gaining more and more importance. Fractionation (fractional crystallization) is a process of separating fats into groups of triacylglycerols with the required technological characteristics (certain melting point, values of iodine number, and saponification number). The essence of the process is that, under the influence of controlled cooling and mechanical processing, the phase (crystals) of fat melt is formed, followed by filtration and splitting of the raw material into two fractions: solid (stearin) and liquid (olein) [147]. Each fraction has its physical and chemical parameters. Since fractionation is a controlled process, it is possible to obtain products of different degrees of hardness, melting temperature, with different triglyceride composition. This process makes it possible to obtain fats with the necessary structural and mechanical properties and physical and chemical parameters without the chemical modification of the original fat; as a result, this process is not accompanied by the accumulation of TIFA [130].

The disadvantage of fats obtained by the method of transesterification and fractionation is their low content of biologically valuable polyunsaturated fatty acids. Additionally, palm oil is used most often as a derivative raw material in the fractionation process, which, as mentioned above, has certain dangers for the human body.

Also, these methods of fat modification are not widespread in Eastern Europe due to the high cost of production.

In this regard, it is relevant to search for the possibility of full or partial replacement of modified fats in the technologies of butter cookies with liquid oils, which are cheaper and more biologically valuable from the point of view of the presence of a significant amount of polyunsaturated fatty acids (PUFA), fat-soluble vitamins, absence of TIFA. Polyunsaturated fatty acids ensure normal growth and metabolism, vascular elasticity, increase the body's resistance to infections and radioactive radiation, participate in the construction of nervous tissue [148]. In the case of a lack of these acids in the body, cholesterol forms complex ethers with saturated fatty acids that accumulate in the blood, which is one of the causes of atherosclerosis. PUFAs are able to form ethers with cholesterol, which are oxidized in the process of metabolism to low-molecular compounds that are easily excreted from the body [149]. According to recent studies, PUFAs reduce the risk of breast cancer, improve the clinical condition of patients with tumors of the pancreas and colon, have a positive effect in the case of rheumatoid arthritis, bronchial asthma, etc. [150]. In addition, they serve as a starting material for the synthesis of cyclic arachidonic acid peroxides in the body, which regulates all activity processes at the cellular level.

The advantages of liquid oils include a high content of dry substances (99.9%), the absence of cholesterol, good digestibility by the human body, ease of transportation, storage, and dosing.

However, the use of liquid oils in the technology of butter cookies is limited due to the occurrence of certain technological problems, which are discussed in the next section.

1.3. Problems of using liquid oils during the production of shortbread cookies and ways of their solution

Today, liquid oils are almost not used during the production of shortbread cookies, which is due to a number of reasons. Firstly, fats in the technology of butter cookies should be used in the form of finely dispersed emulsions, contributing to better distribution of fat particles in thin films between flour particles. This prevents the swelling of flour colloids and the weakening of bonds between the components of the solid phase of the dough. The smaller the thickness of the fat films, the crumblier the finished cookie will be [103]. Liquid oils do not emulsify well; therefore, emulsions formed with them, compared to emulsions based on solid fats, are characterized by less stability. This causes a deterioration in the quality of finished cookies, making the structure more compact, less porous, and crumbliness worsens.

Secondly, liquid oils easily separate from the dough during baking and do not hold the gas bubbles released during the disintegration of leavening agents. This leads to a decrease in porosity and a deterioration in the organoleptic characteristics of the products. Thirdly, they are poorly retained by cookies during storage. As a result, the fat migrates to the packaging materials, causing a deterioration in the appearance and taste characteristics of the finished products [103]. In particular, scientists [109] found that replacing 50% of palm oil with high-oleic sunflower oil increases the degree of fat migration during baking by 20%. It is noted that the mobility of fat largely depends on the amount of STG (Specify what STG stands for) in the fat component – as mentioned above, the optimal content of STG is 15...30% [110] (15...20% [109]). The introduction of liquid oil causes a significant decrease in this indicator. Therefore, its use in cookie technology becomes possible in a mixture with an emulsifier. The use of emulsifiers allows you to reduce the STG content in cookie fat to 5...7% [109].

Thus, to ensure the necessary structural and mechanical properties of the dough and high-quality indicators of finished cookies with the use of liquid oils, additional application of stabilizing additives is necessary. These additives should have high fat-emulsifying, fat-retaining, and moisture-retaining properties [103]. Protein substances, soluble (such as pectins, etc.) and insoluble (such as cellulose) dietary fibers, phospholipids, lecithin, etc., have a stabilizing effect on emulsion systems [151]. It can be assumed that raw materials containing these compounds will have a positive effect on the properties of emulsions for butter cookies and, as a result, on the structural and mechanical properties of the finished product. In addition, highly dispersed solid colloidal particles can be an effective emulsifier, contributing to the formation of so-called Pickering emulsions, in which solid particles are adsorbed at the interphase boundaries of liquids, reducing the surface energy [152].

To stabilize emulsion systems for cookies using liquid oils, it is promising to use additives based on highly dispersed powdered vegetable raw materials. Their advantages also consist in the presence of a complex of nutrients useful for the human body (vitamins, minerals, phenolic compounds, dietary fibers, etc.) in the most accessible and digestible form.

In sugar cookie technology, it is proposed to replace 13.5% of margarine with pumpkin oil or 20% with sea buckthorn oil [153]. Powders from dried apples (6.3% of the mass of finished cookies), raspberry leaves (1.2%), and calendula leaves (0.3%) were used as a stabilizing additive in the pumpkin oil cookie technology. During the production of cookies with sea buckthorn oil, the authors suggest adding powders from dried apricots (4.9%) and medicinal honey (0.3%). The use of pumpkin and sea buckthorn oil allows an increase in the content of polyunsaturated fatty acids in cookies (by 2.5 and 3.3 times, respectively), and the introduction of vegetable powders from fruit and medicinal raw materials enriches the products with pectin substances, dietary fibers, minerals, and vitamins.

The addition of sea buckthorn meal in the amount of 7% to the mass of flour allows the replacement of 20% of fat in shortbread technology with linseed oil [154]. Not only does this enrich cookies with useful nutrients, but it also improves the organoleptic and structural-mechanical properties of the products. The color acquires a golden hue, crumbliness increases, the ability of cookies to get wet improves, and its density decreases.

In works [155, 156], a complete replacement of margarine in shortbread cookies with sunflower refined deodorized oil is proposed. However, this technology involves significant changes in the recipe composition. Wheat flour is completely replaced by corn or rice flour, characterized by high fat-retaining properties [157]. Also, recipe components with high moisture (such as whole milk condensed with sugar, chicken eggs, honey) are replaced by dry powder components (such as skimmed dry milk, egg powder, glucose). In addition, citrus dietary fibers, Herbacel AQ Plus – type N (1% by weight of flour), are added to the recipe [158]. The technological process is also significantly complicated – the preparation of the dough is carried out by brewing a mixture of dry recipe components with sunflower oil with hot (90...100ºC) water, followed by the introduction of chemical leavening agents and flavorings. The advantage of the mentioned technology is obtaining a product for gluten-free food. However, compared to the sample on margarine, there is a slight migration of fat into the packaging materials during the storage process.

A shortbread cookie technology was developed with the replacement of 29% of margarine with liquid oil. Additionally, 2.1% of a mixture of natural vegetable additives with a stabilizing effect (xanthan gum and guar gum, wheat fiber, and soy protein isolate) was added to the mass of the oil [159]. Cookies made using this technology are characterized by the stability of quality indicators during storage – the degree of fat migration into packaging materials is almost the same as in the control sample.

It is proposed to use milk thistle oil (14.7% by mass of raw materials) and linseed oil (8.1% by mass of raw materials) in shortbread technology without changing the amount of recipe fat. To ensure the proper quality of finished cookies, modified starch is additionally included in the recipe (0.7% for cookies with milk thistle oil and 0.5% for cookies with linseed oil) [160].

The possibility of replacing 60% of margarine in shortcrust butter biscuits technology with corn oil was studied [161]. Such a high concentration of liquid oil is possible due to two factors. Althea root powder was used as a stabilizer (2.3% by weight of flour). There is also an additional operation of pre-treatment of corn oil in a special apparatus in a vortex layer of ferromagnetic particles, which leads to an increase in its density. However, such processing causes the formation of a certain amount of transisomers – up to 3.2%.

Innovative is the use of oils to replace solid fats during the production of cookies in the form of oleogel [162, 163]. Oleogels (structured edible oils, molecular gels) are formed as a result of the ability of structuring agents (waxes, phospholipids, monoglycerides, etc.) to self-organize in edible oils. This enables unsaturated liquid oils to maintain a semi-solid state at room temperature without the addition of solid fats [164]. In the study [162], a complete replacement of solid fat in the recipe for cookies with oleogel, obtained from refined sunflower oil and beeswax, was proposed. The cookies made with oleogel showed almost no difference in external characteristics compared to the control but had a firmer texture and lower porosity. However, the widespread use of oleogels in confectionery is hindered by their high cost and market scarcity.

Thus, stabilizing emulsion systems for cookies with the addition of liquid oils are achieved through the use of stabilizing substances as well as unconventional technological methods. The latter approach involves changes in the equipment configuration of the technology, which is economically burdensome. A more promising approach is the use of additional natural raw materials containing stabilizing agents and biologically active components beneficial to the human body. It is noted that the maximum substitution of solid fat with liquid oil in the technology of baked goods when using natural stabilizing substances does not exceed 30%. This emphasizes the relevance of research in finding new natural components that would allow the production of high-quality baked goods using liquid oils.

1.4. Analysis of the chemical composition of the most common nut raw materials in Ukraine

Lately, nuts and their processed products are gaining increasing popularity as healthful foods. Nuts can be categorized into true nuts, which have a dry, woody pericarp (hazelnuts and filberts), and drupes, which are covered by a fleshy pericarp that eventually cracks and falls off, leaving the seed covered by a shell. Examples of drupes include almonds, pistachios, pine nuts, walnuts, and peanuts [165]. All types of nuts are characterized by a high fat content (up to 74%), predominantly unsaturated fats, valuable proteins (up to 25%), vitamins, minerals, and other components essential for human metabolism (Table 1.4 – 1.7).

Table 1.4 – **Main indicators of the chemical composition of nuts most widely represented in the Ukrainian market**

Nutrient	Types of Nuts						
	Pistachios [171, 189]	Almonds [172]	Hazelnuts [169, 191]	Peanuts [167, 170]	Cashews [167, 192]	Pine nuts [174, 182]	Walnuts [16, 171]
Proteins, %	17.8…20.6	18.5…21.22	13.1…17.5	19.6…25.8	13.0…19.5	11.1…17.1	12.2…16.7
Fats, %	43.1…51.6	40.4…52.0	58.2…72.5	40.9…49.6	39.7…62.6	58.7…68.3	60.3…74.5
Carbohydrates, %	11.4…17.2	9.47…15.0	9.5…20.5	9.9…21.5	9.3…32.7	4.8…9.38	7.01…10.8
Dietary Fiber, %	10.3…10.6	1.1…7.0	5.6…7.2	4.0…8.5	2.0…2.5	14.3…15.0	1.5…6.7

The proteins in nuts are considered biologically valuable because they contain all essential amino acids in significant quantities important for the human body. According to studies [167, 187], the highest specific weight in nut proteins is attributed to globulins, which are highly digestible by the human body. It is also noted that the ratio of essential amino acids to non-essential amino acids in nut proteins is 0.45…0.50, which corresponds to the requirements of a balanced diet (this indicator should not be lower than 0.4 [174, 175]).

The lipid content in nuts depends on the variety, type, cultivation conditions, and varies widely – from 39 to 74%. A distinctive feature of nut fats is their high content of polyunsaturated fatty acids (PUFAs) (Table 1.5).

Polyunsaturated fatty acids (PUFAs) are essential, preventing the development of cardiovascular diseases and playing a crucial role in cell growth, maintaining skin health, cholesterol metabolism, and various other processes in the human body [174, 175].

Table 1.5 – **Fatty acid composition of nuts (% of fat mass)**

Fatty Acids	Types of Nuts						
	Pistachios [180, 189]	Almonds [167, 179, 182]	Hazelnuts [177, 178]	Peanuts [167]	Cashews [167, 184, 192]	Pine nuts [176]	Walnuts [181, 182, 187]
Saturated	13.44…14.65	7.8…9.87	8.40…9.89	12.09…16.9	19.34…22.79	22.59…25.12	9.0…11.86
Monounsaturated	50.35…54.16	59.49…68.1	79.09…84.42	78.48…84.56	59.65…63.79	26.34…28.04	14.48…21.9
Polyunsaturated, including:	33.16…36.16	18.7…31.20	7.34…8.08	4.99…5.94	15.7…18.60	45.04…52.45	69.15…75.67
linolenic $C_{18:3}$ (omega-3)	0.73…0.88	0.09…0.12	0.22…0.25	1.52…1.93	0.22…0.25	1.20…1.72	11.4…13.17
linoleic $C_{18:2}$ (omega-6)	32.43…35.28	16.0…31.08	7.12…7.83	3.47…4.01	7.12…15.7	43.84…50.73	57.46…62.50

The highest content of PUFAs is characteristic of the lipid component of walnuts and pine nuts. The ratio of omega-3 to omega-6 fatty acids in the human diet should be 1:4…1:10 [193]. It is noted that the most optimal ratio of these PUFAs is found in walnut fats – 1:5.

A significant indicator of the physiological value of nuts is their high mineral content (Table 1.6).

Table 1.6 – **Content of minerals in nuts (mg/100g)**

Mineral	Recommended daily intake *	Types of Nuts						
		Pistachios [188–190]	Almonds [167, 172, 186]	Hazelnuts [169, 191]	Peanuts [167, 170, 185]	Cashews [167]	Pine nuts [168]	Walnuts [166, 187]
Calcium	1000	97.0… 113.0	248.0… 324.0	96.9… 195.0	54.0… 92.0	33.0… 47.0	13.0… 22.0	87.0… 135.0
Magnesium	400	118.0… 122.0	198.0… 253.0	154.0… 181.0	154.0… 185.0	260… 294.0	236.0… 263.0	124.0… 188.0
Phosphorus	800	455.0… 498.0	451.0… 493.0	303.0… 355.0	349.0… 376.0	482.0… 533.0	537.0… 608.0	315.0… 333.0
Iron	15	3.7… 4.1	2.2… 4.9	1.96… 4.9	4.5… 5.0	6.3… 8.1	5.5… 6.3	2.0… 2.5
Potassium	2000	985.0… 1034.0	672.0… 749.0	617.6… 875.7	705.0… 715.0	553.0… 647.0	518.0… 649.0	316.0… 473.0
Copper	1	0.7…1.3	0.1… 0.2	1.1… 2.2	1.1… 1.2	2.1… 2.2	1.2… 1.4	1.1… 1.4
Manganese	3	1.2…3.8	1.8… 1.9	4.1… 7.6	1.7… 1.9	0.83… 1.6	7.9… 10.2	2.5… 2.9
Zinc	12	2.2…2.8	2.0… 2.3	1.9… 6.3	3.0… 3.27	5.6… 5.8	5.8… 6.7	2.4… 2.6

* Daily norm for the adult population [193].

Minerals should be consumed in sufficient quantities to ensure normal body functioning. For example, zinc accelerates the action of intestinal and bone phosphatases, participates in lipid, protein, and vitamin metabolism. Iron contributes to the formation of red blood cells. Copper enhances the absorption of iron and also participates in the synthesis of red blood cells. Manganese is necessary for the normal functioning of the central nervous system, improves memory, and slows down the development of osteoporosis. Potassium is essential for waste elimination, and in combination with magnesium, it stabilizes the cardiovascular system. Phosphorus serves as an energy carrier, activates vitamins B and D, and, in combination with calcium, is the main structural component of bones and teeth.

It is noted that 100g of nuts can satisfy the daily needs of the body for calcium by 1.3…32%, magnesium by 29.5…73.5%, phosphorus by 37.9…76.0%, iron by 13.1…54.0%, potassium by 15.8…51.7%, copper by 10.0…200.0%, manganese by 40.0…340%, and zinc by 15.8…55.8%.

Equally important for the human body are vitamins, which participate in the synthesis and breakdown of amino acids, fats, nucleic acid nitrogen bases, certain hormones, and acetylcholine, a neurotransmitter that transmits impulses in the nervous system.

It is emphasized that the highest content of vitamin E and B3 is characteristic of almonds and hazelnuts, riboflavin is found in pine nuts, pyridoxine in hazelnuts, and vitamin C and thiamine in pistachios (Table 1.7).

The presented data confirm that nuts are a source of protein, polyunsaturated fatty acids, vitamins, and minerals, making their inclusion in the diet of the population promising, either as individual products or as raw materials for the food industry.

Currently, the most widespread use in food production technologies is peanuts, due to its low cost (Fig. 1.6) [194]. However, among other types of nuts, peanuts are the most allergenic, and there is also a high likelihood of contamination with aflatoxins, which are harmful to the human body (exerting mutagenic, carcinogenic, immunosuppressive effects) [195].

In connection with this, food producers are paying attention to other types of nut raw materials, including walnuts. The prospects of its use in food technologies are determined by several factors. Firstly, compared to other nuts, walnuts have the lowest cost after peanuts. Secondly, walnuts are currently grown in Ukraine on an industrial scale, and their production volumes increase annually.

Table 1.7 – **Content of vitamins in nuts, most widely represented in the Ukrainian market**

Vitamin	Recom-mended daily intake [193]	Types of Nuts						
		Pistachios [188, 189]	Almonds [167, 172, 186]	Hazelnuts [170]	Peanuts [167, 171, 186]	Cashews [192]	Pine nuts [168]	Walnuts [166, 167, 173]
Vitamin E, mg/100g	15	2.2…2.86	23.4… 25.9	18.5… 24.0	8.3…10.1	0.8…0.9	9.0…10.2	2.5…2.7
Thiamine (B_1), mg/100g	1.7	0.8…0.9	0.22…0.37	0.42… 0.48	0.6…0.7	0.4…0.5	0.2…0.5	0.3…0.4
Riboflavin (B_2), mg/100g	2.0	0.1…0.2	0.7…1.0	0.1…0.2	0.1…0.2	0.10…0.22	0.2…0.3	0.1…0.2
Niacin (B_3), mg/100g	20	0.5…1.3	2.9…4.2	0.9…4.0	1.6…1.8	1.2…2.3	0.2…0.4	1.6…1.8
Pyridoxine (B_6), mg/100g	2.0	1.7…2.0	0.2…0.3	0.6…0.7	0.2…0.35	0.26…0.40	0.1…0.2	0.2…0.3
Vitamin C, mg/100g	70	5.3…5.6	0.9…1.4	1.3…2.8	5.2…5.3	0.5…0.6	0.7…0.8	1.41

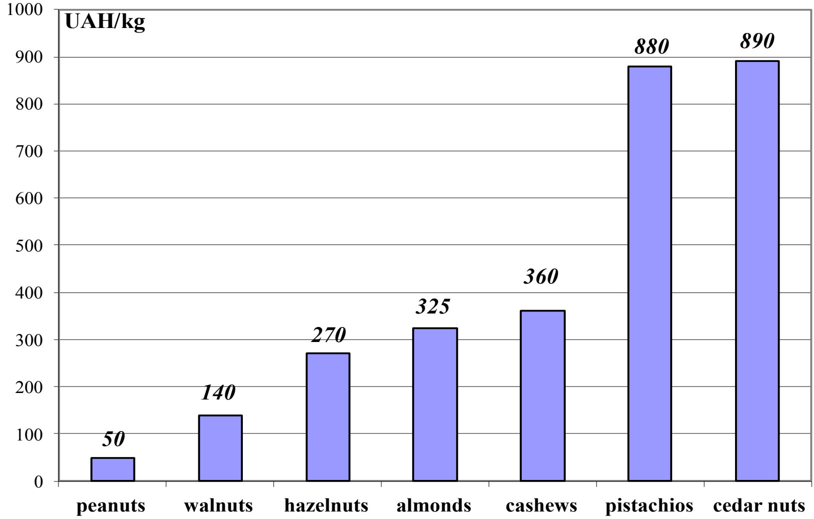


Fig. 1.6. Price per 1 kg of nuts in Ukraine as of June 2022.

According to statistical data [196, 197], in 2018, the area of nut orchards in Ukraine increased by 3%, and Ukraine became the third global leader in walnut production (120,000 tons) after China and the USA. The use of other types of nuts in the food industry is limited due to their high cost. However, consumer interest in products with the addition of unconventional nut raw materials is growing, driven by modern trends in consuming healthy food. This issue can be addressed by using secondary nut raw materials in food production, which remains after the extraction of oils and, compared to whole nuts, has a significantly lower cost while still providing a distinct nutty flavor. Currently, unconventional nuts such as pistachios, almonds, hazelnuts, peanuts, and cashews are not used for oil production. Cedar and walnut are unconventional raw materials for the oil industry. In the process of obtaining oils, about 40% of by-products, including meal and cake, are generated [198]. Cake remains after oil removal using the cold-press method, while meal remains after oil extraction by extraction [199]. As a result, compared to whole nuts, meals and cakes have a higher concentration of physiologically valuable components such as proteins, dietary fibers, minerals, and vitamins, making them promising for improving the physiological value of food products.

1.5. Prospects for the use of cedar and walnut processing products in the food industry

Modern researchers note the high potential of cedar and walnut press cake and meal for their use in food processing technologies (Table 1.8).

Table 1.8 – **Use of cedar and walnut processing products in the food industry**

Raw material	Use direction	Usage features
1	2	3
Cedar nut press cake	Confectionery pastes [200]	Ratio of meal: oil: sugar = 28…33 : 28…29 : 24…26
	Shortbread semifinished product [201]	30% of the flour mass
	Wheat bread [202]	15% of the flour mass
	Liver pates [203, 204]	10% of the meat raw material mass
	Minced meat products [205]	
	Semi-smoked sausages [206]	
	Marzipan [207]	Complete replacement of nut raw material
	Cedar jam [208]	Hydration and boiling with sugar syrup and pectin solution

Continuation of Table 1.8

1	2	3
Cedar nut press cake	Cheese product [209]	1.5 kg per 100 dm^3 of milk
	Mayonnaise [209]	Partial replacement of dry milk and egg products
Cedar nut meal	Gingerbread products [210, 211]	14% of the flour mass, added together with flour
	Ice cream [212]	Introduced in combination with walnut oil
	Rusks [213]	Introduced into the mixture with food bone fat, olive oil, and soy isolate
	Halva [214]	The meal is ground (<0.5 mm) and roasted (moisture 1.0…1.5%)
	Caramel [215]	In the filling composition
	Fermented milk drink [216]	Meal mass fraction – 3%
Walnut press cake	Rye bread [217]	2% to the flour mass
	Culinary products from yeast dough [218]	10% to the flour mass
	Layered pastries [219]	20% to the flour mass
	Air snacks [220]	4…6% to the raw material mass
Walnut meal	Sugar cookies [221]	8% of the raw material mass, added at the emulsion preparation stage
	Butter biscuit [222]	20% of the raw material mass
	Brewed gingerbreads [223]	10% of the raw material mass, added at the dough mixing stage along with flour
	Shortbread cookies [210]	In a mixture of meal seeds of flax: sesame: walnut = 1.5 : 1.5 : 2.0. Dosage – 20% of the flour mass
	Halva [214]	The meal is ground (<0.5 mm) and roasted (moisture 1.0…1.5%)
	Caramel [215]	In the filling composition

The use of cedar nut press cake has been proposed for the production of confectionery pastes [200]. It has been noted that the developed chocolate-nut paste with cedar nut press cake is a plastic mass characterized by a pronounced chocolate-nut taste and aroma, having a uniform color and consistency with slight inclusions of press cake particles. Compared to traditional analogs, the paste has an improved chemical composition, containing polyunsaturated fatty acids, vitamins, and minerals.

Cedar nut press cake is also recommended for enhancing the nutritional value of shortbread semi-finished products (30% of the flour mass) and wheat bread (15% of the flour mass). This allows enriching the products with protein, minerals, and dietary fibers. Structural-mechanical characteristics of the products also improve: the ability to absorb moisture increases in shortbread semi-finished products, and in wheat bread, porosity increases [201, 202].

The use of finely ground cedar nut press cake as a moisture-retaining agent in the technology of liver pâtés [203, 204], minced meat products [205], and semi-smoked sausages [206] has been proposed. Substituting 10% of the meat raw material with this additive not only improves the nutrient composition of the products but also reduces their cost.

D.A. Goncharov recommends using cedar nut press cake to replace nut raw materials in the production of marzipans [207]. D.A. Krivov proposes a technology for cedar jam, which involves soaking cedar nut press cake in water, grinding it, temperature treatment (55…60ºC), and boiling with sugar syrup and pectin solution until the dry matter content reaches 62…70% [208].

A technology for dairy products with the addition of cedar nut press cake has been developed [209], using 1.5 kg per 100 dm^3 of milk. The addition of press cake ensures the production of a product with a tender consistency, pleasant milk-nut flavor, and increases the yield of the finished product (by 31%), attributed to its high water-retaining properties.

The potential for partially substituting dry milk and egg products with cedar nut press cake in mayonnaise production has been established [209]. The high water-retaining and fat-retaining abilities of the press cake contribute to increased mayonnaise yield and improved viscosity. In mayonnaise with cedar nut press cake, the fat content slightly decreases, and the chemical composition significantly improves.

Proposals exist for using cedar nut meal in the technology of preparing gingerbread products [210]. This allows obtaining products enriched with polyunsaturated fatty acids, vitamins, minerals, and an improved amino acid composition. Additionally, the products have a pleasant color, taste, and aroma, characterized by a smooth surface and proper shape. Compared to the control, gingerbreads with added cedar nut meal have a larger volume, a uniform structure upon breakage, lower density, and higher moisture absorption [211].

The unique chemical composition of defatted cedar nut flour (meal) has led to recommendations for its use in ice cream technology [212]. The stabilizing effect of cedar nut meal on the formation of the airy dispersed phase has been established. The whipped soft ice cream depends on the content of defatted cedar nut flour and cedar oil in the recipe, increasing by 5–20%, and the meltdown resistance increases by 3–13%.

A technology for producing dry pastries using a protein-fat emulsion, which includes cedar nut meal in a mixture with edible bone fat, olive oil, and soy isolate, has been developed. The technology allows obtaining products more quickly, reducing the consumption of dry substances for fermentation, and increasing the yield [213].

It is known that cedar nut meal is recommended for processing into confectionery flour, which finds application as fillings for chocolate masses, in the production of marzipans, and special types of flour confectionery products. The process of obtaining flour from cedar nut meal consists of its grinding and sieving on screens [225].

Due to the high content of polysaccharides and oligosaccharides in cedar nut meal, it effectively stimulates the growth of bifidobacteria during milk fermentation. This served as the basis for developing a technology for a fermented milk drink characterized by good organoleptic properties with a pronounced taste of cedar nuts, containing dietary fiber and a large number of viable bifidobacteria [216, 226].

Cedar nut press cake and meal from walnuts are also gaining more and more application in food production technologies.

The use of walnut press cake in the technology of rye bread at a rate of 2% of the flour mass leads to a reduction in baking and drying indicators, promotes an increase in moisture content, and enhances product yield [217].

In the technology of yeast culinary products, the substitution of 10% of wheat flour with walnut press cake is allowed. In this case, the product acquires a light-brown color and a pleasant nutty taste and aroma.

The complete replacement of wheat flour with a mixture of hemp flour and walnut press cake (80:20) is recommended in the technology of shortbread cookies, allowing for the production of gluten-free products [219].

A technology for extruded airy snacks (nut-grain crisps) with the addition of walnut press cake in an amount of 6% of the mass of recipe components has been proposed by Zotova L. V. These snacks are characterized by nutritional balance, high consumer properties, enrichment with vitamins, and minerals [220].

Walnut press cake is currently used in sugar cookie technology (8% of the raw material mass) [221], gingerbread

(10% of the raw material mass) [223], and butter sponge cake (20% of the raw material mass) [222]. Its use has also been proposed in the technology of shortbread cookies as part of a mixture of meal (optimal ratio of meal from flax seeds, sesame seeds, and walnut kernels – 1.5 : 1.5 : 2.0) [224]. The addition contributes to improving the structural-mechanical properties of finished products, reducing alkalinity and density in cookies, increasing moisture absorption, improving shape stability in gingerbread, and increasing porosity in sponge cake. The products are characterized by high organoleptic indicators, acquiring a pleasant nutty taste.

In the confectionery industry, cedar or walnut press cake can be used in a mixture with sunflower mass and powdered sugar as a filling for caramel. This allows obtaining a product with enhanced quality and improved nutritional value [215]. Additionally, these nut press cakes are used to reduce the cost and increase the nutritional and biological value of halva. The press cake is pre-ground to particles no larger than 0.5 mm, roasted until the moisture content reaches 1.0–1.5%, cooled, and ground into powder [214].

Thus, the use of press cakes and meals from cedar and walnut in food production technologies is justified not only from the perspective of improving the nutrient composition of products but also for achieving specific technological effects. These additives have been observed to stabilize emulsion systems (mayonnaises, ice cream, emulsions for sugar, shortbread, and yeast-leavened cookies), act as moisture-retaining agents (pate, sausage products, minced meat products), and positively impact the structure of flour products, among other functions. Considering this, it is considered reasonable to study the possibility of using nut press cakes in yeast-leavened cookie technologies with the use of liquid oils.

Conclusions from Chapter 1

1. The analysis of information sources indicates that current trends in nutrition are focused on increasing the share of physiologically beneficial food products in the diet. Considering the growing demand for flour confectionery products, the prospect of improving the nutrient composition of cookies is noted. The distinctive features of the mentioned raw materials not only determine its high biological value but also provide the opportunity to influence the course of technological processes, the quality of semi-finished products, and finished goods.

2. One potential direction for adjusting the chemical composition of cookies is the partial replacement of the recipe's solid fat with liquid oil, characterized by a low price, absence of trans-fatty acids, and significant biological value. However, the use of liquid oils is accompanied by certain technological problems, such as their emulsifying ability and high mobility during baking and storage, negatively impacting the structural-mechanical and organoleptic characteristics of the products.

3. To stabilize emulsions in cookies with the addition of liquid oils, the use of emulsifiers is necessary. The role of emulsifiers can be fulfilled by high-molecular compounds from plant raw materials (proteins, starches, gums, dietary fibers, etc.) and high-dispersion solid colloidal particles.

4. Analytical research has established that the maximum amount of replacing solid fat with liquid oil in the technology of cookies, when using natural stabilizing substances, does not exceed 30%. This choice of dosage will be further explored in subsequent studies.

5. The chemical composition and cost of basic types of nuts, most prevalent in the Ukrainian market, have been analyzed. The promising use of walnuts in food technologies is emphasized, considering them as an accessible, regional raw

material produced on an industrial scale. The use of other nuts is limited due to their high cost. However, secondary nut raw materials, remaining after oil extraction, have significantly lower costs. The potential utilization of cedar and walnut press cakes in food production has been considered, given that these nuts are industrially processed into oil in Ukraine.

6. The ability of the mentioned additives to stabilize emulsion systems, perform functions as moisture-retaining agents, and positively impact the structure of flour products is recognized. Therefore, further investigation into the application of cedar and walnut press cakes in the technology of cookies with the use of liquid oils is deemed reasonable.

Chapter 2
Characteristics of the chemical composition and functional-technological properties of cedar and walnut meal

The peculiarities of the chemical composition of cedar and walnut meal not only determine their impact on the nutritional and biological value of baked goods when used but also influence the behavior of these additives during the course of technological processes. Therefore, the goal of the research presented in this section was to investigate the chemical composition of cedar meal (CM) and walnut meal (WM) (Fig. 2.1).

a b

Fig. 2.1. Photographic depiction of the research objects: a – CM (Cedar Meal); b – WM (Walnut Meal)

Despite the fact that these products are obtained after extracting oil using the cold-press method followed by grinding and essentially represent the pressed cake, the manufacturing company markets them in their commodity form as "meal." Cedar meal has a creamy color, a light aroma, and a taste reminiscent of cedar nuts. Walnut meal distinguishes itself with a more saturated color (light brown) and a pronounced walnut flavor (Table 2.1).

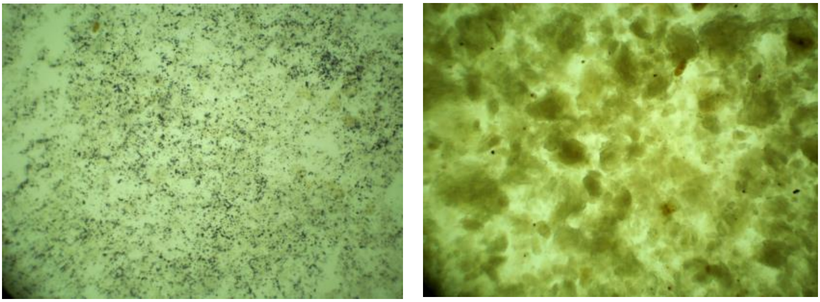
Table 2.1– **Characteristics of quality indicators for the researched additives**

Indicator	Characteristics of Meal	
	Cedar meal	Walnut meal
Appearance	Fine-dispersed powdery product	
Taste	Pleasant nutty flavor	
Odor	Characteristic of cedar nuts	Characteristic of walnuts
Color	Creamy color	Light brown
Moisture, %	8.3 ± 0.3	8.8 ± 0.3
Acidity, grad	0.88 ± 0.2	1.3 ± 0.2

2.1. Study of the chemical composition of cedar and walnut meal

At the initial stage of the research, microscopic examination of the walnut meal samples was conducted at a magnification of 160 times, utilizing various indicators for staining (Lugol's solution, Sudan III, a solution of fluorescein with sulfuric acid, and a solution of NaOH) for the clear identification of the possible chemical composition.

When examining the investigated additives under the microscope (at a 160-fold magnification), small cells of the seed core, densely filled with aleurone grains, were observed in the walnut meals. Upon treatment with Lugol's solution, the presence of starch grains in the walnut meals was identified, with a noticeable difference in size – starch grains in Walnut Meal (WM) surpass those in Cedar Meal (CM) in terms of size (Fig. 2.2).



a b

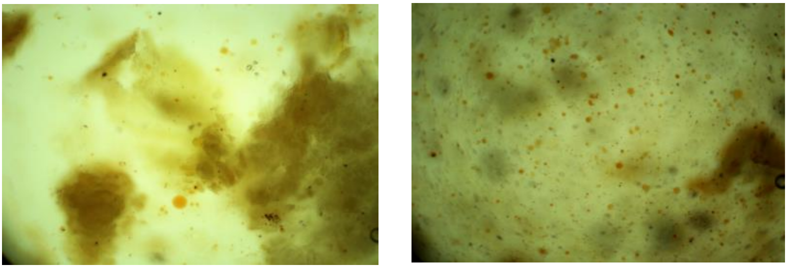
Fig. 2.2. Microscopic examination results of the investigated samples stained with Lugol's solution (×160): a – CM; b – WM

It is also determined that the starch grains in CM are colored in a blue-violet shade, while those in WM turn reddish-violet. Considering this, it can be noted that the starch in CM is predominantly represented by amylose, while in WM, it is amylopectin.

Treatment of walnut meals with Sudan III reagent allowed the identification of the presence of small oil droplets in the additives, which, upon contact with the specified indicator, acquire an orange coloration (Fig. 2.3).

Additionally, brown fragments of the husk covering the walnut kernels are visible in the field of view, with pores from a group of sclerenchyma cells. The walls of these cells are curved and uniformly thickened, along with fragments of vascular bundles (Fig. 2.4).

Under the influence of fluorescein with sulfuric acid, the sclereids and vascular bundles of the husk are colored in a pink hue (Fig. 2.5, 2.6), indicating the presence of dietary fibers, including lignin, in the additives.



a b

Fig. 2.3. Microscopic examination results of the investigated samples stained with Sudan III (×160): a – CM; b – WM

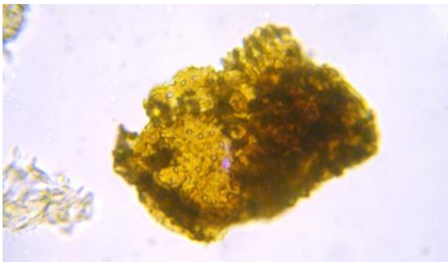
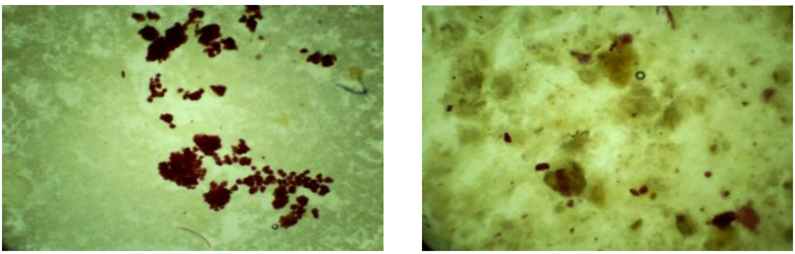


Fig. 2.4. Fragment of the husk with pores covering the walnut kernel, exemplified by WM (magnification ×100)

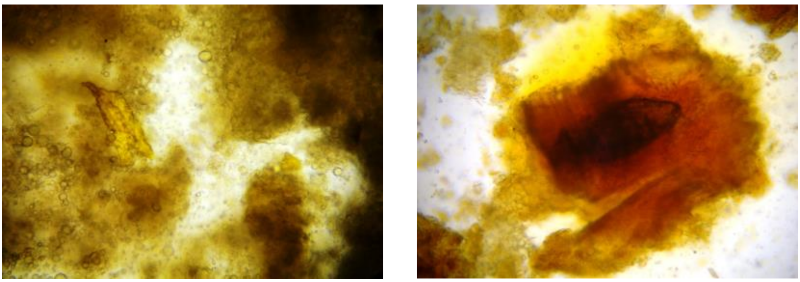


a b

Fig. 2.5. Microscopic examination results of the investigated samples stained with fluorescein with sulfuric acid (×160): a – CM; b – WM

Fig. 2.6. Microscopic examination results (×400) stained with fluorescein with sulfuric acid, exemplified by WM

Upon staining the examined samples with NaOH solution, lemon-yellow fragments are observed (Fig. 2.7), which may indicate the presence of fruit septum fragments.



a b

Fig. 2.7. Microscopic examination results of the investigated samples stained with fluorescein with sulfuric acid (×160): a – CM; b – WM

The determination of the composition features of cedar and walnut meal was carried out using the IR spectrometry method. A comparison of the IR spectra of CM and WM indicates their similar qualitative chemical composition, attributed to the similarity in the position and intensity of absorption bands (Fig.2.8).

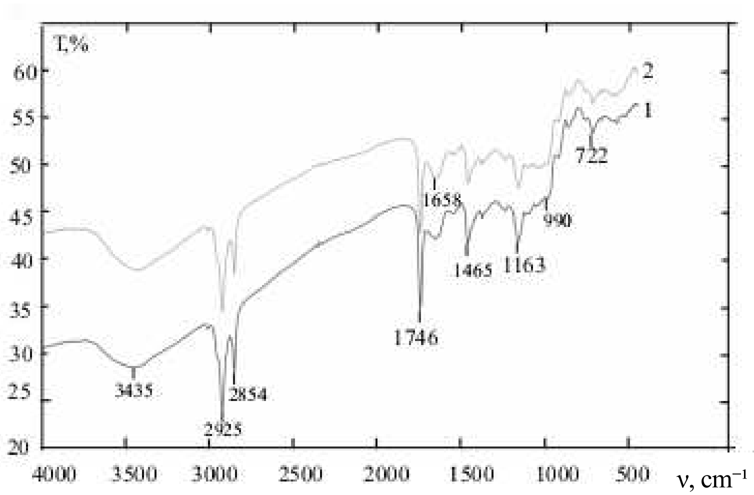


Fig. 2.8. IR spectra of walnut meal samples: 1 – WM, 2 – CM

The assignment of absorption bands in the IR spectra of the investigated samples is presented in Table 2.2.

The broad absorption band in the range of 3000–3600 cm^{-1} is associated with the stretching vibrations ν(OH). The absorption bands at 2924 and 2854 cm^{-1} are related to the symmetrical and asymmetrical stretching vibrations of the C–H bond in the CH_2 groups [227]. The absorption band at 1746 cm^{-1} corresponds to the stretching vibrations of C=O in the protonated carboxyl group COOH, 1545 cm^{-1} νas(C=O), 1415 cm^{-1} νs(C=O) – asymmetrical and symmetrical stretching vibrations of the COO^- groups in carboxylic acids and amino acids, and 1240 cm^{-1} – vibrations of ν(C–O) [228]. The absorption band at ~1380 cm^{-1} may be associated with deformational vibrations of the C–OH bond in carbohydrates [229].

Table 2.2 – **Assignment of absorption bands in the IR spectra of walnut meal samples**

Intensity of Absorption, cm^{-1}		Functional Groups
CM	WM	
3435	3435	$\nu(OH)$
2925	2924	$\nu_{as}(-CH_2-)+\nu_{as}(-CH_3)$
2854	2854	$\nu_s(-CH_2-)+\nu_s(-CH_3)$
1746	1746	$\nu(C{=}O)$
1654	1658	$\nu_{as}(C{=}O)+\sigma(HOH)+\delta_d(NH_3^+)$
1544сл	1545	$\nu_{as}(C{=}O)+\delta_d(NH_3^+)$
1465	1465	$\nu_s(C{=}O)+\delta(OH)+\delta_{as}CH_2+\delta_s(NH_3^+)$
1377	1380	$\delta(OH)+\delta_s(CH_2)$
1243	1237	$\delta(CH_2)+\nu(C–C)+\nu(C–O)$
1163	1163	$\nu(C–C)+\omega(CH_2))$
1050	1048	$\nu(C-O)+\delta(OH)$
988	990	$\delta(CH)+\delta(OH)$
927	924	$\delta(CH)$
864	864	$\delta(OH)$.
722	721	$\rho(CH_3)+\delta(=C-H)$
-	-	$\rho(COO^-)+\delta(C–C)$

The experimental research results (Figure 2.2) confirm that the IR spectra of WM and CM samples exhibit absorption bands at 3435, 2925, 2854, 1746, 1654 (1658), 1545, 1465, 1380, 1237 (1243), 1163, 988 (990), 827 (824), and 720 cm^{-1}. The absorption band with a maximum at 3435 cm^{-1} is associated with the stretching vibrations of ν(OH) [230]. Bands at 2925 cm^{-1} and 2854 cm^{-1} can be attributed to the stretching vibrations of the C–H bond in CH_2 groups [227]. Deformational (δ) vibrations of C–H bonds are represented by bands with maxima at 1465 cm^{-1} (δsCH_3) and 1380 cm^{-1}

($\delta_s CH_3$ and CH_2). There are also absorption bands related to the stretching vibrations of the carboxyl group in organic, amino, and fatty acids ν(C=O) at 1746 cm^{-1}, 1545 cm^{-1} νas(C=O), and ν(C–O) at 1237 cm^{-1} [228]. Bands at 1465 cm^{-1} and 1654 cm^{-1} may coincide with bands of ionized carboxyl groups νs(C=O), deformational vibrations of protonated amino groups $\delta_s(NH_3^+)$, and deformational vibrations of hydroxyl groups δ(OH) (Table 2.2) [231].

The presence of double bonds in polyunsaturated fatty acids in the meal samples is indicated by absorption bands corresponding to the stretching vibrations of the C–H bond in the =CH– group, manifesting in the 3005 cm^{-1} region. This band does not overlap with the bands of saturated C–H bonds in the $–CH_2$ and $–CH_3$ groups. Bands related to out-of-plane deformational vibrations of unsaturated C–H bonds are observed at 722 cm^{-1} (cis-compounds), and the vinyl groups show bands at 990 and 927 cm^{-1} (δC–H in the groups $=CH_2$ and >C=CH–) [232]. Thus, the presence of these functional groups in the spectrum confirms the existence of polyunsaturated fatty acids, amino acids, proteins, flavonoids, organic acids, and carbohydrates in the meal samples.

According to the literature [231], the bands in the 1000–1200 cm^{-1} range observed in the meal spectra can be utilized for the identification of pectin substances. The presence of the pyranose ring, which is part of pectin substances, is confirmed by the frequencies of absorption bands in the IR spectrum at 1163 cm^{-1} (vibrations of pyranose rings and C–O). Bands at 1050 cm^{-1} may also be associated with symmetric vibrations of OH groups in flavonoids. It is known that pectin molecules contain residues of galacturonic acid in the ionized form. All carboxyl, amino, and hydroxyl groups form a single system of hydrogen bonds [232].

Since the direct use of IR spectroscopy for the quantitative determination of individual components in food systems is quite challenging, the assessment of meals regarding the content of valuable nutrients was conducted using the method [234] based on the calculation of the relative optical density using the formula:

$$K_i = \frac{D_i}{D_{ст}} \tag{2.1}$$

where K_i is the relative optical density; D_i is the optical density of a specific transmission band; D_{ct} is the optical density of the selected reference band.

For the quantitative assessment of components in the samples, key characteristic absorption bands were selected, which, according to literature data, can be attributed to functional groups that're part of the molecule of a particular nutrient. The band at 3434 cm^{-1} was chosen as an internal standard for the meals of cedar and walnut (Fig. 2.2).

According to the provided methodology [234], the values of the relative optical density for CM and WM were calculated (Table 2.3).

Table 2.3 – **Relative optical density values for nut meal samples**

Samples	The values of relative optical density for the absorption band νν, cm^{-1}									
	1163	1243	1377	1465	1544	1654	1746	2855	2924	3434
CM	0.70	0.64	0.65	0.70	0.64	0.69	0.84	1.01	1.14	1.00
WM	0.79	0.73	0.74	0.78	0.71	0.77	0.90	1.01	1.13	1.00

Based on the data from IR spectroscopy analysis and the values of the relative optical density of the investigated nut meals, it can be concluded that in terms of the content of various functional groups related to polyunsaturated fatty acids, organic acids, and flavonoids, cedar nut meal somewhat lags behind walnut meal [235, 236]. The results of the analysis of IR spectra allow conclusions to be drawn about the qualitative chemical composition of CM and WM. In the next stage, quantitative values of the chemical composition indicators of the additives were investigated using generally accepted methods. Given that the purpose of the work was to study the possibility of using nut meals in the technology of bakery products, it was considered appropriate to compare the features of the chemical composition of some indicators of the investigated additives and wheat flour of a higher grade, as one of the main recipe components for baking.

At the first stage, the content of nutrients and dietary fibers in the nut meals was evaluated (Table 2.4).

Table 2.4 – **Content of nutrients and dietary fibers in nut meals and wheat flour of a higher grade**

($p \leq 0,05$, $n=5$, $\sigma=3,0 \ldots 5,0\%$)

Substance	Cedar nut meal	Walnut meal	Wheat flour of higher grade [237]
Proteins, %	38.08	33.63	10.3
Fats, %	7.05	12.18	1.1
Carbohydrates, % including	45.62	45.17	70.9
Monosaccharides	3.67	6.23	0.7
Oligosaccharides	7.36	12.53	0.9
Starch	15.84	15.45	67.7
including amylose	11.76	1.03	24.9
amylopectin	4.08	14.42	42.8
Non-starch polysaccharides	18.79	10.99	1.6
including hemicellulose	12.65	5.16	1.5

An important indicator of the chemical composition is the presence of a significant amount of protein in the nut meals - 38.08% and 33.63% in CM and WM, respectively.

From a physiological standpoint, the quality of protein in a product is crucial, not just the quantity. The quality is characterized by the presence of essential amino acids and their balance, reflecting the proximity to "ideal protein." The quality (biological value) of proteins is determined by the amino acid score, which reflects the ratio of essential amino acids contained in 100 g of protein in the investigated product to their quantity in 100 g of ideal protein.

During the calculation of amino acid scores, data on the amino acid composition of the proteins in wheat flour of higher grade (according to informational sources [237]) and information regarding the amino acid composition of CM and WM (based on the results of our own experimental studies [238, 239]) were used (Table 2.5).

Table 2.5 – **Amino acid scores of nut meals and wheat flour**

№	Amino acid	Amino acid score of proteins, %		
		Cedar Meal (CM)	Walnut Meal (WM)	Wheat Flour
1	Threonine	98.19	91.05	65.53
2	Valine	105.2	110.78	75.73
3	Methionine + Cysteine	117.14	103.10	83.22
4	Isoleucine	98.75	108.98	104.37
5	Leucine	89.29	99.73	117.89
6	Tyrosine + Phenylalanine	95.04	127.83	121.36
7	Tryptophan	267.68	111.11	97.09
8	Lysine	123.26	54.59	44.13

Analysis of the results presented in the table indicates that the proteins in nut meals surpass the proteins in flour in terms of amino acid score for almost all amino acids. In particular, compared to flour proteins, the proteins in CM and WM have a better amino acid score for threonine (1.5 and 1.4 times, respectively), valine (1.5 and 1.4 times), methionine and cysteine (1.4 and 1.2 times), tryptophan (2.8 and 1.14 times), and lysine (2.8 and 1.2 times). The amino acid score for other amino acids in the nut meals is approximately at the same level as in the flour.

It has been established that leucine is the limiting amino acid for CM proteins (the amino acid score is 89.29%). Lysine is the limiting amino acid for both WM and wheat flour of the higher grade. However, the amino acid score for lysine in WM is 54.59%, and for wheat flour, it is 44.13%. For CM proteins, the amino acid score for lysine is 123.26%.

The study of the fractional composition of nitrogen-containing compounds in supplements has shown that CM contains three times more protein substances of the albumin and globulin fractions and almost twice as many proteins of the prolamin fraction compared to WM (Table 2.6). The proteins of walnut meal are predominantly represented by glutenins.

The indicated features of the protein composition of the samples can significantly influence their behavior in food systems, particularly determining the presence of certain surfactant properties.

The fat content in CM and WM is 7.05% and 12.18%, respectively (Table 2.4). A distinctive feature of the fats in these additives is their high biological value, driven by a significant proportion of unsaturated fats, as evidenced by chromatographic studies of the fatty acid composition of the lipid component of nut meals. It is noted (Table 2.7) that the fats in WM are characterized by a higher degree of unsaturation than CM.

Table 2.6 – **Fractional composition of nitrogen-containing compounds in nut meal**

($p \leq 0,05$, $n=5$, $\sigma=3,0…5,0\%$)

Fractions of nitrogen-containing compounds	Content of nitrogen-containing fractions			
	g/100 g of the product		% of the total protein content	
	CM	WM	CM	WM
Water-soluble (albumins)	2.86	1.17	7.22	3.37
Salt-soluble (globulins)	10.91	2.74	27.51	7.89
Alcohol-soluble (prolamins)	8.27	4.78	20.84	13.79
Alkali-soluble (glutenins)	16.55	24.94	41.72	71.95
Non-protein nitrogen	0.60	0.4	2.72	3.07

The content of unsaturated fats in WM is 95.79% of the total fat content, while in CM, it is 80.19%. It is known that the higher the degree of unsaturation of a fatty acid, the more susceptible it is to oxidation [240], necessitating quality control of the lipid component in cookies with the addition of these supplements during storage.

The fats of these additives have a similar content of polyunsaturated fatty acids. However, linolenic acid predominates in the composition of CM, while linoleic acid prevails in WM. The ratio of ω-3:ω-6 for the lipid component of CM is 1:0.06, and for the fats of WM, it is 1:1.3. The optimal ω-3:ω-6 ratio in nutrition should be 1:(4…10).

Therefore, walnut meal can be recommended for use in food technologies that include components containing polyunsaturated fatty acids ω-6.

It has been established that the investigated samples of walnut meal have almost the same amount of carbohydrates (45.62% and 45.17% for CM and WM, respectively) (Table 2.4).

Table 2.7 – F**atty acid composition of nut meal fats according to chromatographic analysis**

($p \le 0{,}05$, $n=5$, $\sigma=3{,}0…5{,}0\%$)

Fatty acids	Content, % of fat mass	
	in CM	in WM
Saturated, including:	**18.99**	**4.21**
lauric $C_{12:0}$	-	0.04
myristic $C_{14:0}$	0.77	0.06
pentadecanoic $C_{15:0}$	1.95	-
palmitic $C_{16:0}$	8.58	0.49
palmitic $C_{18:0}$	4.79	1.79
arachidic $C_{20:0}$	0.36	1.11
behenic $C_{22:0}$	0.77	0.29
tricosanoic $C_{23:0}$	0.30	-
tetracosanoic $C_{24:0}$	2.31	0.43
Monounsaturated, including:	**27.03**	**40.97**
palmitoleic (ω-7) $C_{16:1n9}$	0.06	20.68
oleic (ω-9) $C_{18:1n9}$	26.97	20.29
Polyunsaturated, including:	**53.16**	**54.82**
linoleic (ω-6) $C_{18:2n9,12}$	2.89	31.41
linolenic (ω-3) $C_{18:3n9,12,15}$	50.27	23.41

Wheat flour, in terms of carbohydrate content, exceeds the samples of meal by more than 1.5 times. However, the carbohydrates in wheat flour are mainly represented by starch, while the carbohydrates in the meal are predominantly dietary fibers (Table 2.4). In terms of fiber content, CM and WM exceed wheat flour by 4.7 and 2.7 times, respectively.

It is also noted that WM contains a significant amount of mono- and oligosaccharides (67% higher than CM).

In terms of starch content, the investigated samples of walnut meal are practically indistinguishable. However, the starch in CM is mainly represented by amylose, while in WM, it is amylopectin. The obtained data correlate with the results of microscopy of additives – it is known that iodine gives a violet coloration to amylose. During the interaction of iodine with amylose, which has a helical structure, inclusion complexes (clathrates) are formed, in which iodine molecules are embedded inside the spiral structure of the amylose molecule, accompanied by a change in color to blue-violet. Unlike amylose, amylopectin gives a weak red-violet coloration with iodine.

Dietary fibers of additives consist of non-starch polysaccharides and lignin. Non-starch polysaccharides make up about 41% of all carbohydrates in CM and about 24% in WM. It has been determined that CM is characterized by a high content of hemicellulose and pectin substances – 2.5 and 1.3 times more than WM, respectively. It is noted that the cellulose content in WM is higher compared to CM by 2 times. The lignin content in CM and WM is 0.04 and 0.03%, respectively. It is known that non-starch polysaccharides have a positive effect on the activity of beneficial intestinal microflora, stimulate its peristalsis, and serve as enterosorbents, among other functions.

Vitamins, minerals, and minor components of food, including phenolic compounds and organic acids, play a significant biological role in the human body.

Experimental data indicate that CM and WM have high vitamin value. CM and WM surpass flour in the content of vitamin E (by 3.6 and 1.5 times, respectively), vitamin B1 (by 3.1 and 2.2 times, respectively), and B5 (by 3.8 and 1.9 times, respectively) (Table 2.8).

Table 2.8 – **The content of vitamins and minerals in nut meal**

($p \le 0{,}05$, $n=5$, $\sigma=3{,}0…5{,}0\%$)

Substance	Daily Norm*, mg/100g	Content, mg/100 g		
		In CM	In WM	In high-quality wheat flour [242]
1	*2*	*3*	*4*	*5*
Vitamins				
E	15	5.5	2.2	1.50
C	60	trace	1.3	trace
B1	1.4	0.77	0.541	0.25
B2	1.6	0.22	0.15	0.04
B3	18	1.35	trace	1.20
B5	6	1.15	0.570	0.3
B6	2.0	0.14	trace	0.17
Minerals				
Iron	15	4.6	14	1.2
Potassium	2000	1280	920	122
Calcium	1000	21.7	275	18
Silicon	25	0.13	90	4
Magnesium	400	385	275	16
Manganese	3	19	11.5	2.8
Copper	1	4.5	2.3	0.5

Continuation of Table 2.8

1	*2*	*3*	*4*	*5*
Phosphorus	800	320	160	86
Sodium	1300	6.4	4.6	3
Nickel	0.02	0.64	0.9	0.3
Zinc	12	25	14	2.01
Lead	0.5**	<0.03	0.05	-
Ash Content	-	0.91	0.20	0.5

* Daily norm for the adult population [193]

** Maximum permissible concentration

Research into the mineral composition of nut meal has shown (Table 2.8) that in terms of the content of examined mineral substances, nut meals significantly exceed wheat flour. In particular, compared to wheat flour, CM contains more iron by 3.8 times, potassium by 10.5 times, calcium by 1.2 times, magnesium by 14.8 times, and phosphorus by 3.7 times. WM surpasses wheat flour in these indicators by 11.7, 7.5, 15.3, 17.2, and 1.9 times, respectively.

It has been calculated that the daily norm of manganese is contained in 20.1 g of WM and 15.8 g of CM, copper in 43.5 g and 22.2 g, zinc in 85.7 g and 48.0 g, nickel in 2.2 g and 3.1 g of the respective nut meal. The research also showed that 100 g of WM contains 360% of the daily silicon requirement, 93% iron, 96.2% magnesium, 46% potassium, 27.5% calcium, and 20% phosphorus. 100 g of CM will provide 64% of the daily potassium requirement, 96.2% magnesium, and 40.0% phosphorus.

Heavy metals (lead) in the examined nut meals are present in small quantities, about 10–15 times less than the established maximum permissible concentration, which is due to the barrier functions of nutshells.

Modern nutritional studies emphasize the important biological role of so-called minor components of food, including certain phenolic compounds. Phenolic compounds exhibit antioxidant, antimicrobial, and immunostimulatory effects on the body. Therefore, it was deemed appropriate to determine the content of phenolic compounds in the examined nut meals. Considering that wheat flour of a higher grade does not contain such substances, the subsequent series of studies did not compare it with wheat flour.

A series of qualitative reactions were carried out to detect the presence of phenolic compounds in nut meals (Figure 2.9, Table 2.9). For this purpose, alcoholic extracts from CM and WM were used.

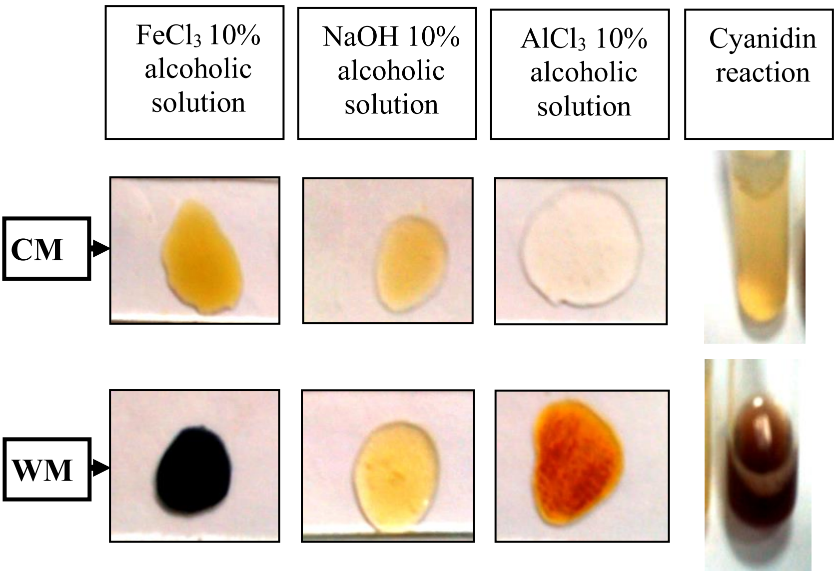


Fig. 2.9. Identification of the presence of phenolic compounds in nut meal

Table 2.9 – **Results of qualitative reactions for the presence of phenolic compounds in nut meal**

Method and analysis conditions	Analytical effect for the extract		Group of phenolic compounds
	CM	WM	
$FeCl_3$ 10% alcoholic solution	yellow	dark blue	tannins
NaOH 10% alcoholic solution	light yellow	brick-red	hydroxycinnamic acids
$AlCl_3$ 10% alcoholic solution	light yellow	yellow	flavonoids
Cyanidin reaction	yellow-pink	brown-pink	

Qualitative differences in the composition of phenolic compounds were identified for CM and WM. The presence of intense dark-blue coloration in the extract from WM with a 10% alcohol solution of $FeCl_3$ indicates a high content of tannins in it. Additionally, this extract has a more intense coloration in reactions with 10% alcohol solutions of NaOH, $AlCl_3$, and in the cyanidin test. This fact suggests that compared to CM, WM contains a larger amount of hydroxycinnamic acids and flavonoids. The quantitative analysis of these compounds is presented in Table 2.10.

Table 2.10 – **Content of phenolic compounds in nut meal**

($p \leq 0,05$, $n=5$ $\sigma=3,0…5,0\%$)

Indicator	Content, mg/100 g		Recommended daily intake, mg/day [193]
	ШКГ	ШВГ	
Hydroxycinnamic acids	20	50	10
Tannins	1380	4270	200
Flavonoids	1	60	85

The sum of hydroxycinnamic acids was determined in terms of chlorogenic acid, tannins were determined in terms of tannin, and flavonoids were determined in terms of rutin. Notedly, compared to CM, WM is characterized by a higher content of hydroxycinnamic acids – 2.5 times, tannins – 3.1 times, and flavonoids – 60 times. To meet the daily needs of the body for hydroxycinnamic acids, one can consume 50 g of CM or 20 g of WM. The daily amount of tannins is contained in 15 g of CM or 4.7 g of WM. While the content of flavonoids in CM is negligible, 100 g of WM contains about 70% of the daily norm of these compounds.

The composition of nut meal primarily includes amber, citric, and malic acids, as determined by chromatographic studies (Fig. 2.10, 2.11).

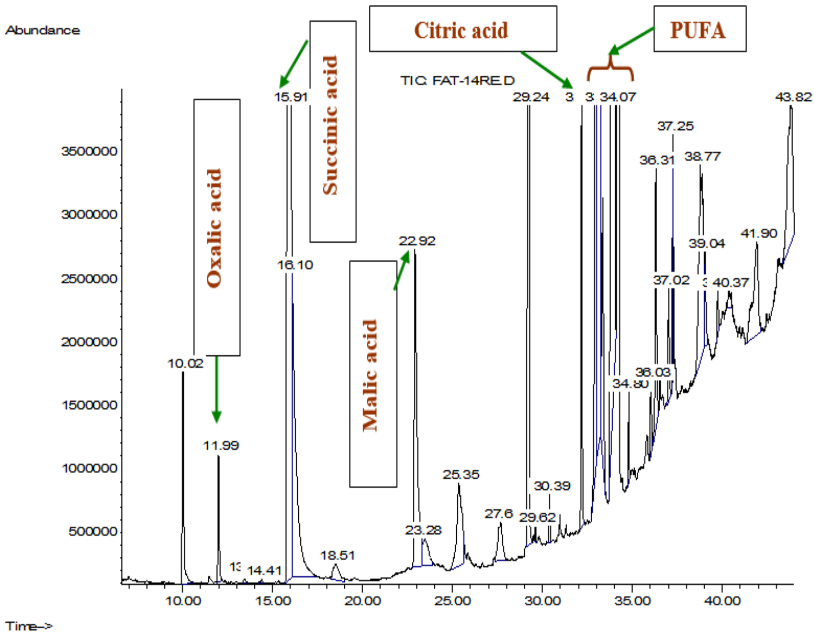


Fig. 2.10. Chromatographic studies of cedar nut meal

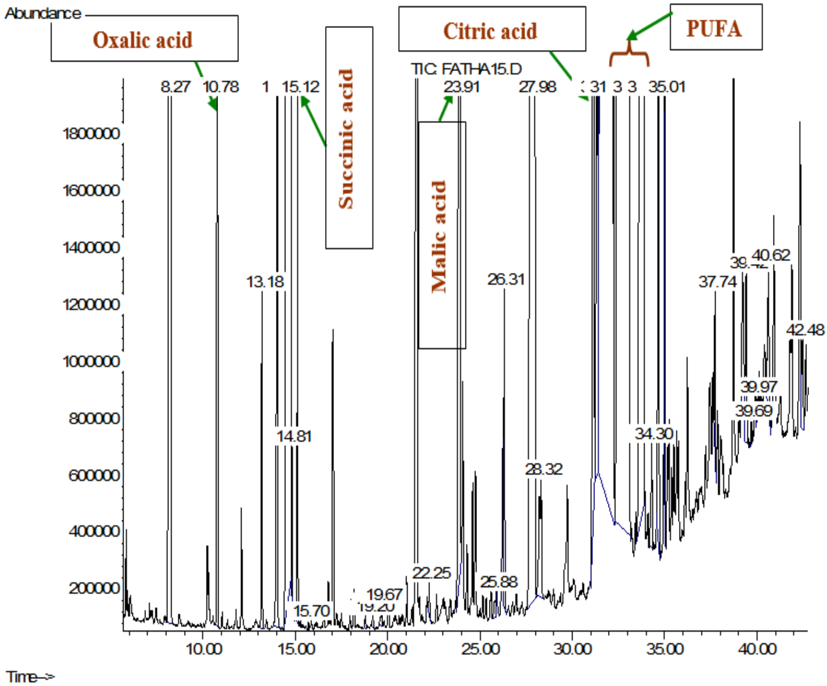


Fig. 2.11. Chromatographic studies of walnut meal

Table data (Table 2.11) indicate that WM, compared to CM, is characterized by a higher content of malic acid (5.3 times) and fumaric acid (100 times). CM contains more citric acid (2.9 times) and succinic acid (2.2 times). Considering that the recommended intake of organic acids is about 500 mg/day, CM and WM cannot be considered a source of these substances. However, their use in food production will slightly increase the content of these nutrients.

A comparative analysis of walnut meal from walnuts and cedar nuts showed that they have a similar qualitative chemical composition.

Table 2.11 – **Content of organic acids in nut meal**

($p \leq 0,05$, $n=5$, $\sigma=3,0...5,0\%$)

Polybasic carboxylic acids	Content, mg/100 g	
	in CM	in WM
Citric acid	8,1	2,80
Malic acid	7,30	39,00
Fumaric acid	0,07	7,00
Succinic acid	8,00	3,60

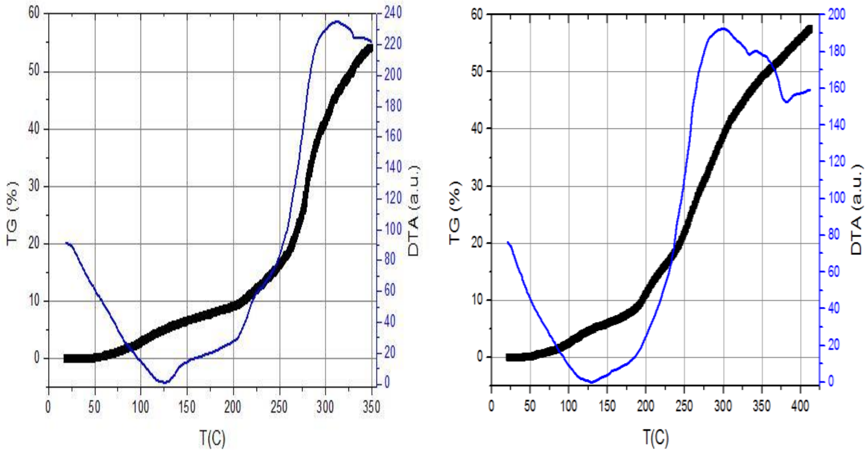
It is noted that CM, compared to WM, is characterized by a higher content of proteins, dietary fibers, vitamins, some minerals (potassium, magnesium, manganese, copper, phosphorus, and zinc), but lags behind in the content of phenolic compounds, polyunsaturated fatty acids, iron, calcium, and silicon.

The next stage of the research involved studying the moisture content in the nut meal.

2.2. Study of the state of moisture in nut meal

The distribution of moisture in the meal is important in terms of its functional and technological properties. The degree of its association with protein and carbohydrate components will influence the formation of the structural-mechanical properties of semi-finished products and the behavior of food systems during storage [241].

The assessment of the moisture content in the meal was carried out based on the kinetic parameters of endothermic processes occurring with a change in mass, according to derivatographic studies (Fig. 2.12).



a b

Fig. 2.12. Thermograms of the experimental samples: a – CM; b – WM

Derivatograms of the meals exhibit characteristic temperatures of hydration stages, substance decomposition, and temperature intervals of stability of intermediate compounds, determined by peaks of endothermic effects accompanied by moisture evaporation and release of gaseous fractions.

Continuous mass loss of the samples is observed throughout the entire range of investigated temperatures, amounting to 54.2% and 57.8% for CM and WM, respectively, of the mass of the studied samples. The thermogravimetric curve can be conventionally divided into four regions of thermal transformations (Appendix A, Table A1).

For the first region, a mass loss is characterized by the loss of free water (7.73% for CM and 6.36% for WM). The second region involves the loss of bound water (6.88% for CM and 9.94% for WM). The third region includes the removal of part of the bound water and the decomposition of organic components (26.94% and 32.28%, respectively). The fourth region corresponds to the final decomposition and evaporation of organic components (12.6% and 10.0%, respectively).

The DTA curve (Fig. 2.12) shows several endothermic peaks (for CM at temperatures of 125, 202, 241°C, for WM at 130 and 185°C) and exothermic peaks (for CM at temperatures of 310 and 343°C, for WM at 300, 343, 356, and 396°C) (Appendix A, Table A2).

Establishing temperature zones for the investigated samples of meal additives (Appendix A, Fig. A1, Fig. A2) in conjunction with the analysis of the obtained results allowed determining the quantitative ratio of moisture in different forms of binding in the supplements (Table 2.12).

Table 2.12 – **Results of derivatographic analysis**

Type of Meal	Total Moisture, %	Type of water by form of binding, % of total moisture				
		free	bound			
			physically-mechanically	osmo-tically	adsor-ption	chemi-cally
CM	8,3	3	9	21	30	37
WM	8,8	4	22	25	23	26

It is noted that CM and WM practically do not differ in terms of the free moisture content indicator, but for the content of physically-mechanically bound moisture (classified as weakly bound), WM exceeds CM by 2.4 times. This is due to the fact that this type of moisture is retained in the product by macro- and microcapillaries, and WM is characterized by a cellulose content 2 times higher than in CM, which has a capillary structure. The better ability of WM to bind water physically-mechanically and osmotically will determine its higher (compared to CM) hydrophilic properties in technological systems.

The next stage of the work involved studying the functional and technological properties of nut meal supplements.

2.3. Analysis of functional-technological properties of nut meal

The functional and technological properties of powdery raw materials largely depend on the degree of its grinding, i.e., its particle size distribution [242]. Therefore, it was considered expedient to assess the particle size distribution of CM and WM compared to high-grade wheat flour.

The particle size distribution of nut meals was determined by the microscopic method at 120x magnification [243]. The results of the experiment are presented in the form of the differential function of particle distribution (Fig. 2.13).

Experimental data indicate that the experimental supplements are finely dispersed powders with similar particle size distribution (Table 2.13). For instance, particles with a size of up to 40 μm constitute 50% CM, 46% WM, and only 29% flour. The high dispersion of the supplements results in the manifestation of certain functional and technological properties. The smaller the particle size of the supplements, the larger their specific surface area and the better their interaction in a dispersed state with the surrounding environment.

The key functional and technological properties that allow evaluating the impact of supplements on the quality of bakery products include water-holding, fat-holding, and fat-emulsifying capacities.

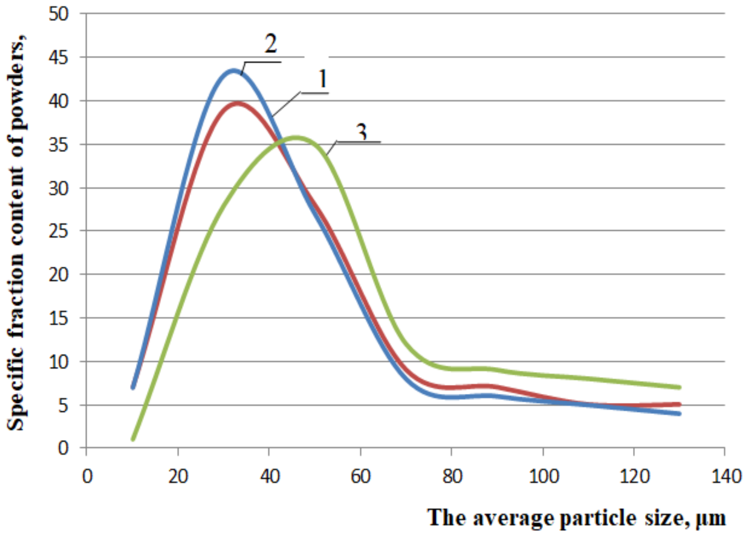


Fig. 2.13. Differential particle size distribution function: 1 – CM, 2 – WM, 3 – high-grade wheat flour

Table 2.13 – **Particle size distribution of supplements and high-grade wheat flour**

Sample	Particle size distribution of supplements (%), µm						
	up to 40	40… 60	60… 80	80… 100	100… 120	120… 140	Average particle diameter, µm
CM	50	27	8	6	5	4	48.8±1.5
WM	46	28	9	7	5	5	51±1.5
High-grade wheat flour	29	35	12	9	8	7	60.4±2.5

Water-holding capacity (WHC) characterizes the hydrophilic properties of additives and reflects the intensity of the intermolecular interaction between water and the surface of their particles. WHC depends on the type of polymers present in the additives, the size, density, and the state of the surface of their particles. Considering that the main moisture-retaining component in the cookie recipe is flour, an assessment of the WHC of additives was carried out in comparison with high-grade wheat flour.

The evaluation of the WHC of samples was conducted under the influence of various temperatures (from 20 to 90°C), determined by the baking stage in the cookie manufacturing process (Fig. 2.14).

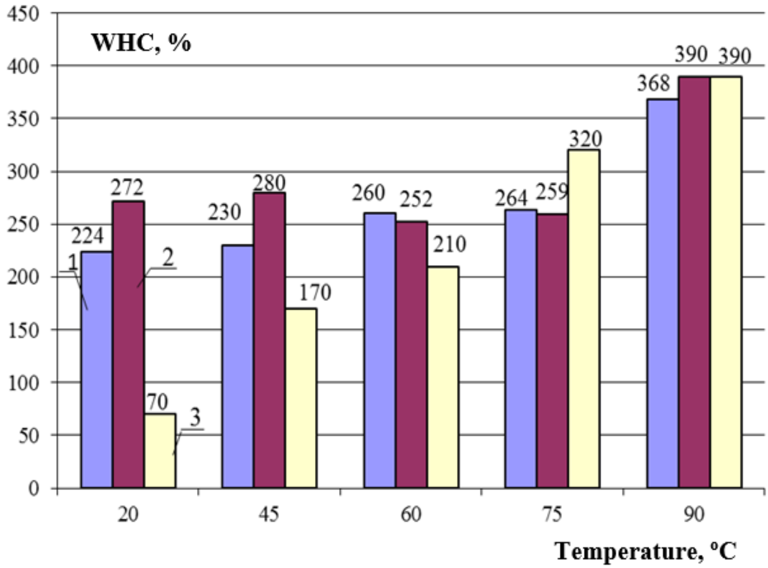


Fig. 2.14. Water-holding capacity at different temperatures: 1 – CM, 2 – WM, 3 – high-grade wheat flour

The investigation of water-holding properties of experimental additives revealed that at a temperature of 20ºC, they exhibit a higher WHC value compared to wheat flour. Specifically, at this temperature, CM exceeds flour in WHC by 3.2 times, and WM – by 3.9 times. This can be explained by the smaller particle size of the additives (Table 2.13) and the characteristics of the protein-polysaccharide composition of the examined samples. The higher hydrophilic properties of CM and WM at 20ºC are due to the presence of a significant amount of dietary fibers (18.79% and 10.99%, respectively), proteins (38.59% and 33.63%), and the porous structure of their particles (Table 2.4). Despite the higher content of these biopolymers in CM, it slightly lags behind WM in its water-holding capacity. This can be explained by the qualitative composition of hydrocolloids. Specifically, CM proteins contain a considerable amount of albumin and globulin fractions (their total content is 13.77 g/100 g of meal, while for WM – 3.91 g/100 g of meal). Additionally, despite the fact that experimental meals contain the same amount of starch (Table 2.4), the starch in CM is represented by amylose (the ratio of amylose to amylopectin is 11.76 : 4.08), while in WM, it is represented by amylopectin (the ratio of amylose to amylopectin is 1.03 : 14.42). Furthermore, experimental additives differ in the composition of dietary fibers – CM contains a significant amount of water-soluble hemicellulose and pectin substances (12.65% and 5.2%, respectively, compared to 5.16% and 3.95% in WM). As a result, soluble dietary substances (albumins, globulins, amylose, hemicellulose, and pectin), when dissolving in liquid, increase its relative viscosity and slow down the swelling of insoluble polysaccharides, including cellulose. It is known that cellulose has a large number of hydroxyl groups and is characterized by a developed system of fine submicroscopic capillaries, which determines its high water-holding properties [244]. Considering that the cellulose content in WM is 2 times higher than in CM, it exhibits a higher water-holding capacity.

At a temperature of 45ºC, there is active swelling of dietary fibers and starch grains, leading to an increase in the WHC indicator in experimental samples. Due to the significantly higher starch content in wheat flour (70%) compared to the investigated additives, intensive increases in the WHC values are characteristic for wheat flour in this temperature range. Upon heating to 60 and 75ºC, protein denaturation occurs, resulting in almost no change in the WHC value for CM, while it decreases for WM. This may be related to a deeper protein denaturation in WM. Additionally, it is possible to assume that since the starch grains in nut meal are smaller than those in wheat starch, they tend to gelatinize at higher temperatures, resulting in an increase in the WHC of nut meals only at 90ºC.

In the case of raising the temperature to 90ºC, a more pronounced tendency for an increase in the WHC value is observed in wheat flour – by 5.6 times, while for CM, this increase is 1.6 times, and for WM – 1.4 times. This is due to the fact that about 78% of the starch in wheat flour consists of amylopectin, which, compared to amylose, has better hydrophilic properties due to its high molecular weight and branched structure. However, amylopectin is located inside the starch grain and can only be released after the grain's shell is destroyed, which occurs at temperatures above 60ºC (for wheat starch), explaining the significant increase in WHC in the temperature range of 60…90ºC.

The fat emulsifying capacity of experimental additives was evaluated in relation to various types of fats: liquid oil (refined and deodorized sunflower oil), margarine, and cream butter. The choice of fats was justified by their widespread use in confectionery technology. Solid fats were used in a plasticized state. It was found that CM exhibits almost identical fat emulsifying properties in relation to cream butter and margarine – FEC is 32.7 and 32.1%, respectively (Fig. 2.15).

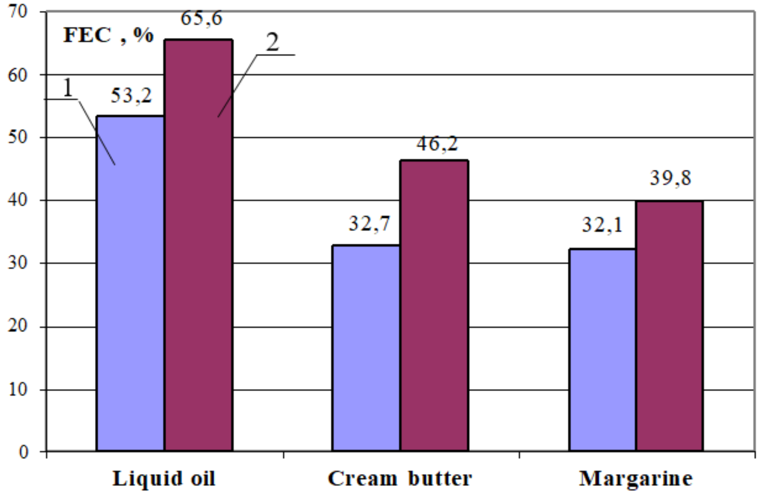


Fig. 2.15. Fat emulsifying capacity in relation to different fats: 1 – CM, 2 – WM

In WM, the emulsifying capacity for cream butter is 16.1% higher than the emulsifying capacity for margarine. The fat emulsifying capacity (FEC) of the investigated samples in relation to liquid oil is significantly higher than that in relation to cream butter and margarine. For CM, it is 62.7% and 65.7%, respectively, and for WM, it is 42.0% and 64.8%. This can be explained by the fact that margarine and cream butter are essentially emulsions in which surfactants such as lecithin, monoglycerides, and others act as emulsifiers. The stabilizing effect of emulsifiers is due to the fact that their molecules have hydrophilic and hydrophobic functional groups, which orient appropriately at the interface of phase separation, reducing surface tension.

In this process, hydrophilic substances bind to a part of the dispersed medium and form a protective solvating envelope around the fat droplet. It can be assumed that the introduction of the investigated meal into the emulsion system significantly increases the amount of emulsifiers. Consequently, a second layer of stabilizer molecules is formed on the surface of fat droplets, with functional groups oriented in the opposite direction. This fact leads to a decrease in the stability of the system [245].

Thus, nut meals exhibit higher emulsifying properties in relation to liquid oil than to solid fats traditionally used in bakery technology (margarine and cream butter).

Therefore, the fat-holding capacity of the experimental samples was assessed specifically in relation to liquid oil. Considering that one of the main technological challenges hindering the use of liquid oils in the technology of shortcrust butter biscuits is their migration during baking, the study of fat-holding capacity was conducted in the temperature range from 20 to 140ºC (Fig. 2.16).

It has been established that throughout the entire investigated temperature range, WM exhibits better fat-holding properties than CM. It is noted that the fat holding capacity (FHC) values for CM and WM in the temperature range from 20 to 60ºC increase by 1.9 times, in the range of 60 to 80ºC, the FHC of the experimental samples hardly changes, and under the influence of temperatures 100 to 140ºC, it begins to decrease.

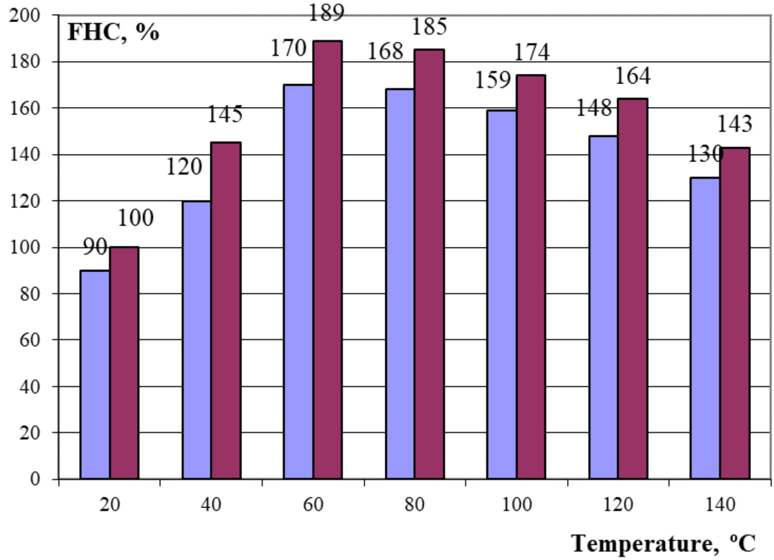


Fig. 2.16. Fat-holding capacity of nut meals at different temperatures: 1 – CM, 2 – WM

The high fat-holding capacity of nut meals is attributed to their finely dispersed state, which ensures high availability of hydrophobic groups during dispersion in fat. Additionally, the dietary fibers and protein substances of the additives have a porous structure, allowing for the physical binding and retention of free fat. The improvement in FHC of the additives when heated at temperatures of 40 and 60 ºC can be explained by the thermal denaturation of proteins. As a result, the conformation of the protein molecule changes, releasing hydrophobic segments that were previously grouped inside the molecule. The decrease in FHC of nut meals when heated from 100 to 140 ºC may be due to the destruction of protein molecules. It can also be assumed that interactions occur between proteins and other components, leading to the formation of protein-carbohydrate and protein-lipid complexes, accompanied by a general decrease in functional groups in the protein molecule.

It is known that an important characteristic of plant raw materials is the presence of enzymes and their activity, which can affect the state of biopolymers in wheat flour during the dough kneading process and the quality of the product during storage. The state of the enzymatic complex of CM and WM was evaluated based on the activity of proteolytic, amylolytic enzymes, as well as lipase and lipoxygenase (Table 2.14).

Table 2.14 – **Enzymatic activity of CM and WM compared to high-grade wheat flour**

($p \le 0{,}05$, n=5, σ=3...5%)

Enzyme name, unit of measurement	Enzymatic activity		
	High-quality wheat flour	CM	WM
Proteolytic Enzymes, mg of nitrogen per 100g DS	23.50	22.09	4.84
Amylolytic Enzymes, mg of starch/hour, including:	27.10	20.00	34.10
α-amylase	0.70	6.90	4.2
β-amylase	27.00	13.48	19.18
Lipase, ml/cm^3	0.54	1.16	0.90
Lipoxygenase, ml/cm^3	0.01	0.04	0.01

From the provided data, it can be noted that the activity indicators of proteolytic enzymes CM and WM are lower compared to wheat flour by 1.41 and 18.66 mg of nitrogen per 100 g of dry substance (DS), respectively. Additionally, the meal exhibits higher activity of α-amylase by 6.2 and 3.5 mg of starch/hour, respectively. In nut meals, unlike wheat flour, lipase and lipoxygenase show insignificant activity, which may affect the quality of baked goods with additives during storage. However, the indicated enzymatic activity in the meals is low enough not to have a significant impact on the deterioration of the lipid complex [246].

Thus, the results of the conducted research complex demonstrate that the experimental additives are finely dispersed powders with high water-holding, fat-holding, and fat-emulsifying properties.

Conclusions from Chapter 2

1. The cedar and walnut meals are characterized by a similar qualitative chemical composition. Both CM and WM contain a significant amount of proteins (38.08 and 33.63%, respectively) with high biological value. The proteins in CM and WM have a better amino acid score for threonine, valine, methionine, cysteine, tryptophan, and lysine compared to wheat flour.

2. CM and WM contain 7.05 and 12.18% fats, respectively, with a high degree of unsaturation. Linolenic acid predominates in CM, while linoleic acid predominates in WM. Nut meals have almost the same amount of carbohydrates (45.62 and 45.17% for CM and WM, respectively), mainly represented by dietary fibers (41 and 24%, respectively).

3. In terms of mineral content and vitamins, nut meals significantly surpass wheat flour, providing a basis for reducing the required amount of flour in cookie recipes when using these additives. The additives also contain a physiologically significant amount of phenolic compounds

(mostly hydroxycinnamic acids, tannins, and flavonoids in WM, and hydroxycinnamic acids and tannins in CM).

4. Derivatographic studies reveal that WM has a greater ability to bind water physically and osmotically compared to CM, resulting in higher hydrophilic properties in technological systems.

5. Particle size analysis indicates that nut meals have a higher degree of dispersion than wheat flour. Fifty percent of CM, 46% of WM, and only 29% of wheat flour have particle sizes up to 40 micrometers.

6. The additives exhibit high water-holding and fat-holding capacities. Walnut meals show higher emulsifying properties compared to liquid oil (sunflower), especially in comparison to solid fats traditionally used in bakery technology (margarine and butter), providing a basis for partially replacing solid fat with sunflower oil in recipes.

7. Compared to high-grade wheat flour, CM and WM have lower indicators of proteolytic activity. In terms of lipase and lipoxygenase activity, nut meals surpass wheat flour insignificantly.

CHAPTER 3
TECHNOLOGICAL SUBSTANTIATION OF THE USE OF CEDAR AND WALNUT MEAL DURING THE PRODUCTION OF BUTTER SHORTBREAD COOKIES WITH LIQUID OILS

3.1. Analysis of the influence of nut meal on the properties of wheat flour biopolymers

The properties of flour products significantly depend on the characteristics of the raw material included in their composition. One of the primary recipe components for sandy layered butter biscuits is high-grade wheat flour. When mixing flour with water, its components form a hydrated cohesive mass known as dough. The key role in the formation of such dough belongs to insoluble proteins in the flour, namely gliadin and glutenin. The high hydration capacity of these proteins is due to the presence of hydrophilic groups in their molecular structure, located on the surface of the protein globule. Protein molecules can retain double to triple their weight in water, causing them to significantly expand in volume. As a result of mechanical action during kneading, they extend beyond the boundaries of the starch granules in the form of films and filaments, sticking together to form a sponge-like network structure, known as the gluten framework. The strength of this framework is determined by the strength of gluten. The quality and quantity of gluten are the primary factors characterizing the baking properties of flour and, consequently, guiding its application. The introduction of additional raw materials can have a certain impact on the technological properties of flour, influencing the quality of semi-finished products and the final product. Considering this, during the investigation of the potential use of any new recipe component in the technology of flour-based products, it is advisable to determine its influence on the properties of gluten.

The objects of the study were medium-strength wheat flour and mixtures (flour + nut meal), in which the content of CM and WM amounted to 5, 10, 15, and 20% of the flour mass. The influence of additives on the technological properties of the flour was assessed by changes in the indicators of quantity and quality (hydration capacity, elasticity, extensibility, ball spreading) of gluten, as well as by the physical and structural-mechanical properties of the dough.

The results of the study on the impact of cedar and walnut meals on the content and properties of gluten in high-quality wheat flour are presented in Table 3.1.

Table 3.1 – **Characteristics of gluten in high-quality wheat flour at different contents of CM and WM**

($p \leq 0,05$, $n=5$, $\sigma=3...5\%$)

Sample	Additive dosage, %	Indicator					
		Raw gluten content, %	Dry gluten content, %	Hydration capacity, %	Elasticity, IU	Extensibility, cm
Without additive (control)	0	29.9	10.4	186	80	13
With CM	5.0	29.1	10.3	183	75	10.5
	10.0	28.2	10.2	177	70	9.5
	15.0	25.9	9.5	171	65	8.5
	20.0	22.0	8.2	168	60	7.5
With WM	5.0	27.6	10.0	175	73	10.0
	10.0	26.2	9.6	172	69	8.5
	15.0	22.2	8.2	169	63	5.5
	20.0	17.9	6.7	165	57	4.5

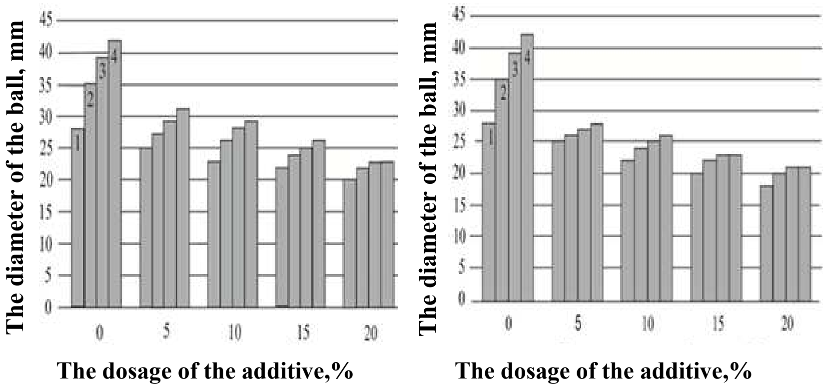
It has been established that the introduction of CM in amounts of 5.0% and 10.0% has almost no effect on the content of raw and dry gluten – the changes in these indicators are within the experimental error.

In case of increasing the dosage of CM to 15% and 20%, the amount of raw and dry gluten decreases relative to the control sample by 13.4% and 26.4%, respectively. It is noted that WM has a more significant effect on these indicators. Under the conditions of introducing 20% of this additive, the reduction in the amount of raw and dry gluten is 40.1% and 35.6%, respectively. In our opinion, the reduction in the amount of gluten can be explained by several factors. Firstly, the studied additives contain fats (in CM – 7.05%, in WM – 12.18%), which, by distributing on the surface of protein molecules, screen their hydrophilic compounds and limit the swelling and structuring of protein micelles. As a result, proteins that have not swollen are washed away along with starch and other components. Due to the fact that WM contains more fats than CM, the tendency to reduce the amount of gluten in samples with this additive is more pronounced. Secondly, the additives contain a significant amount of non-starch polysaccharides, which have a high water-absorbing capacity and, as a result, compete with the biopolymers of flour for moisture absorption. They are also capable of forming protein-polysaccharide complexes with the protein substances of the flour, which will not form gluten.

The above also explains the decrease in the hydration capacity of gluten. In particular, under the conditions of the maximum investigated dosage of CM and WM, the hydration capacity of gluten proteins decreases by 9.7% and 11.3% relative to the control sample.

The extensibility of samples decreases with an increase in the dosage of additives (for samples with CM – by 19.2…42.3%, for samples with WM – by 23.1…65.4%), which is caused by the disruption of the integrity of the gluten framework due to the distribution of CM and WM particles among the flour particles.

Research on elasticity indicators (Table 3.1) and ball spread of gluten (Figure 3.1) indicates its strengthening. In particular, when adding CM to the flour mixture in the amount of 5.0…20.0%, a decrease in the gluten elasticity indicator by 6.3…9.7% relative to the control sample is noted. For systems with similar WM content, this indicator decreases by 8.8…28.8%. It has been established that the ball spread indicator of gluten after 180 minutes in samples with CM and WM decreases compared to the control by 1.4…1.8 and 1.5 and 2.0 times, respectively. The strengthening effect on gluten may be exerted by the phenolic compounds present in the investigated nut meal, which are capable of forming complexes with proteins [247].



a b

Fig. 3.1. The effect of CM (a) and WM (b) on the spread of gluten ball over: 1 – 0 min, 2 – 60 min; 3 – 120 min; 4 – 180 min

Additionally, the fats in the additives are mainly represented by polyunsaturated fatty acids, which, during oxidation, form peroxide compounds. Peroxides and hydroperoxides contribute to the oxidation of sulfhydryl groups in protein molecules, leading to the formation of disulfide bonds that strengthen the intramolecular structure of gluten and promote its densification [248]. The higher content of fats and phenolic compounds in WM contributes to its more pronounced strengthening effect on gluten proteins.

The obtained data correlate with the results of rheological properties of dough samples with the addition of nut meals, obtained on the alveograph (Table 3.2) (Appendix B).

Table 3.2 – **Results of alveograph analyses for the investigated dough samples**

($p \leq 0,05$, $n=5$, $\sigma=3...5\%$)

Sample	Dosage of additive, %	Elasticity (P), mm	Extensibility (L), mm	Dough balance (P/L)	Specific work of elastic deformation (W), cm²	Elasticity index, %
Without additive (control)	0	54	108	0.5	190	57
With CM	5.0	56	83	0.7	196	52
	10.0	77	61	1.5	200	51
	15.0	90	54	1.7	213	47.3
	20.0	-	-	-	-	-
With WM	5.0	65	78	1.0	229	57
	10.0	105	66	1.6	242	46
	15.0	125	52	1.8	264	42
	20.0	-	-	-	-	-

The inability to investigate dough samples with an additive content of 20% of the flour mass is noted due to the limitation of the technical characteristics of the device, which may be caused by the fact that dietary fibers complicate the formation of an elastic gluten framework.

It is established that the introduction of CM in the amount of 5.0% does not affect the dough's elasticity indicator. Increasing the dosage of CM to 10 and 15% contributes to an increase in this indicator by 1.4 and 1.7 times, respectively, while the extensibility of the test samples decreases by 1.8 and 2.1 times, respectively. It is noted that WM has a more significant impact on the rheological properties of the dough. Under the conditions of dosages of this additive in the investigated range, the dough elasticity indicator increases by 1.2–2.3 times, and the dough extensibility indicator decreases by 1.4–2.1 times, respectively. As a result, there is an increase in the dough balance indicator compared to the control by 3.4 and 3.6 times for the maximum amount of CM and WM. The increase in the specific work of elastic deformation (W) in samples with nut cake also indicates an increase in the strength of the flour.

The water absorption capacity of flour mixtures, consistency, formation time, stability, and thinning of the investigated dough samples were determined on the Brabender farinograph (Appendix B). It is established that the introduction of the investigated nut cakes contributes to an increase in the water absorption capacity of the dough (Table 3.3).

Table 3.3 – **Results of the farinograph analysis of the investigated dough samples**

($p \leq 0,05$, $n=5$, $\sigma=3...5\%$)

Sample	Dosage of additive, %	Dough characteristics			
		Water absorption capacity, %	Mixing time, $\tau \times 60^{-1}s$	Stability, $\tau \times 60^{-1}s$	Extensibility, unit
Without additive (control)	0	62.3	2.5	4.5	65
With CM	5.0	62.9	2.9	4.2	100
	10.0	63.9	3.4	3.9	130
	15.0	65.6	3.8	2.8	145
	20.0	66.5	4.2	2.5	155
With WM	5.0	64.4	2.8	3.9	120
	10.0	65.3	3.1	3.1	145
	15.0	66.2	3.4	2.7	170
	20.0	67.8	3.8	1.4	190

In particular, the values of this indicator for dough systems with the addition of 15 and 20% CM exceed the control sample by 5.3 and 6.7%, and for systems with WM - by 6.2...8.8%, respectively. This dynamic can be explained by the higher water-holding properties of CM and WM compared to flour (by 2.7 and 2.9 times, respectively). The dough formation time with the addition of CM and WM increases by 1.2...1.7 and 1.1...1.5 times, respectively. A more pronounced tendency to change this indicator is characteristic of CM. Perhaps this is due to the high water-absorbing capacity of CM, which is due to the presence of a significant amount of dietary fiber, which requires more time for complete hydration. While the hydrophilic properties of WM are associated with a significant amylopectin content, which requires less time to swell.

Additionally, the use of CM and WM contributes to a decrease in dough stability (by 1.1...1.8 and 1.2...3.2 times, respectively) and an increase in its degree of aeration under the action of mechanical processing (by 1.5...2.4 and 1.8...2.9 times, respectively).

The obtained results can be explained by the dehydrating ability of the sugars in the additives (the monosaccharide content in WM is almost 2 times higher than in CM, which slows down the hydration of dough hydrocolloids) and the higher activity of their α-amylases compared to wheat flour, which contributes to the intensification of starch hydrolysis. The obtained data correlate with the results of studying the "falling number" indicator of the water-flour suspension with additives (Fig. 3.2).

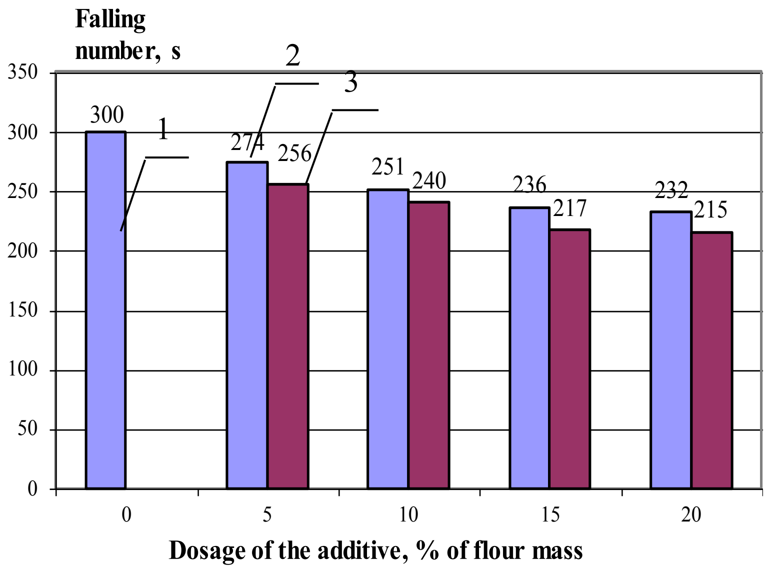


Fig. 3.2. Effect of additives on the "falling number" indicator of wheat flour: 1 – without additives (control); 2 – with CM; 3 – with WM

From the diagram, it can be seen that the value of this indicator decreases from 300 s in the control to 232 s in the sample with 20% CM and to 215 s in the sample with the same content of WM. Previous studies have shown that the α-amylase activity of WM is 1.6 times higher than that of CM, resulting in a more intensive decrease in the "falling number" indicator when added to water-flour suspensions.

Thus, the addition of WM and CM contributes to a reduction in gluten yield, decreases its hydration capacity, which is due to the formation of protein-polysaccharide complexes between the dietary fibers of the additives and the proteins of the flour.

A strengthening effect of the additives on gluten has been identified, manifested in certain changes in the physical and structural-mechanical properties of the dough. The strengthening effect of nut meals is caused by the presence of tannins and lipid oxidation products. However, it has been found that the dietary fibers of the additives complicate the formation of an elastic gluten framework, which can be considered positive for making dough for shortcrust butter biscuits. Considering the above, it is advisable, when using CM and WM in shortcrust butter biscuits technology, to reduce the flour content.

3.2. Study of the effect of nut meal on emulsion properties for butter cookies

From the conducted literature review, it has been established that during the production of shortcrust butter biscuits, it is possible to replace part of the solid fat with liquid oil. However, according to information sources, the maximum amount of oil that can be introduced into the emulsion system for shortcrust butter biscuits is 30% of the mass of solid fat;

ensuring the stability of quality indicators of such a sample is only possible with the additional addition of emulsifiers to the system.

From previous studies (section 2), it has been found that CM and WM possess high fat emulsifying and fat holding properties, making it reasonable to explore their potential use for stabilizing the quality characteristics of emulsions (fat + batter) for shortcrust butter biscuits using liquid oils. Samples of emulsions for butter biscuits were studied on margarine (recipe No. 160 [249]) and with the substitution of 30% margarine with liquid oil. Refined deodorized sunflower oil was used as the liquid oil. The possibility of using nut meals in such a system in an amount of up to 20% of the total mass of recipe components for butter biscuits was studied. It was found that when 20% nut meals were added, the emulsion became too thick. In such samples, excessive swelling of the hydrocolloids of the additives occurs, resulting in a dense emulsion that, according to the results of test laboratory baking, does not allow obtaining the characteristic structure of shortcrust butter biscuits. Therefore, in this series of studies, samples of emulsions with the substitution of 30% margarine with liquid oil and the addition of nut meals at dosages of 10 and 15% of the total mass of recipe components for butter biscuits were evaluated. The emulsion was prepared for 15×60 s at a stirring speed of 5 s^{-1}. The margarine was used in a plasticized state (t=37…38ºC). The quality of the emulsions was evaluated based on indicators of dispersion, stability, and effective viscosity..

It has been established (Fig. 3.3) that the stability of the emulsion obtained from a mixture of margarine and oil is 37.5% lower compared to the control on margarine alone. The addition of 10% CM and WM contributes to the improvement of the stability of such emulsion by 20.0% and 32.0%, and the addition of 15% nut meals results in an improvement by 48% and 56%, respectively.

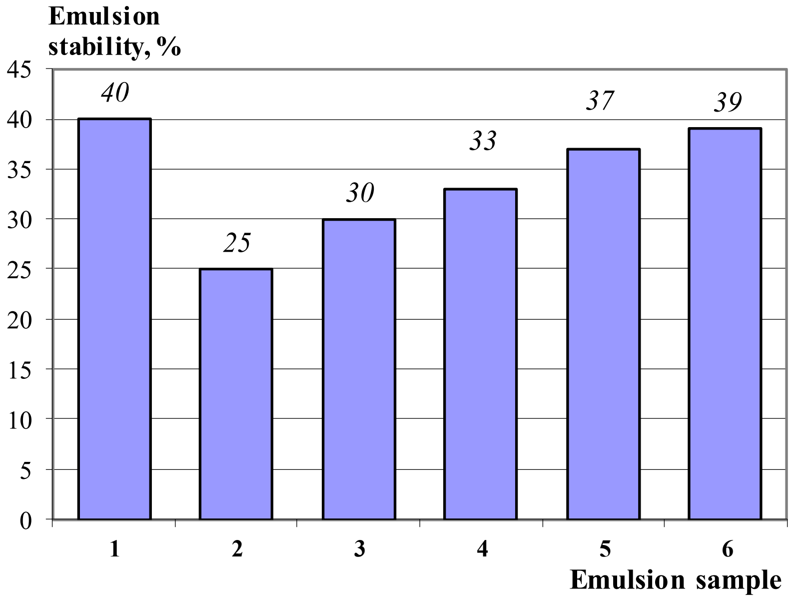


Fig. 3.3. Emulsion stability for shortcrust butter biscuits: 1 – on margarine; 2, 3, 4, 5, 6 – on a mixture of margarine and oil (2 – without additives; 3 – with 10.0% CM; 4 – with 10.0% WM; 5 – with 15.0% CM; 6 – with 15.0% WM)

It is noted that emulsion samples with the addition of 15% CM and WM are closest to the control sample in terms of stability, which had margarine as its fat base. This correlates with the results of emulsion dispersion studies (Table 3.4) and microscopic analysis (Fig. 3.4).

It is known that the stability of an emulsion depends on its dispersity and uniformity – the larger the proportion of smaller fat droplets, the higher the stability of the emulsion against separation [250].

Table 3.4 – **Dispersion of the investigated emulsion samples**

($p \leq 0,05$, n=5, σ=3...5%)

Sample of emulsion	Distribution of fat globules (in %) by size, μm				
	Up to 2	2…4	4…6	6…8	More than 8
On margarine (Fig. 3.4, a)	3	10	45	24	18
On a mixture of margarine and oil					
Without additives (Fig. 3.4, b)	2	11	28	35	24
With 10% CM	13	30	26	18	13
With 10% WM	15	34	24	16	11
With 15% CM (Fig. 3.4, c)	19	40	23	14	4
With 15% WM (Fig. 3.4, d)	20	42	20	12	6

From the research results (Table 3.4), it can be observed that the replacement of 30% margarine with liquid oil leads to an increase in the number of large fat droplets in the emulsion. Specifically, in the control sample, 45% consists of fat globules with a size of 4–6 μm, and 24% with a size of 6–8 μm. In the sample with a combined fat base, the quantity of globules with a size of 4–6 μm decreases to 28%, while the fat globules with a size of 6–8 μm and more than 8 μm increase to 35% and 24%, respectively. It is noted that the addition of 15% nut meal contributes to an increase in the number of fat globules with a size of 2–4 μm by more than 4 times.

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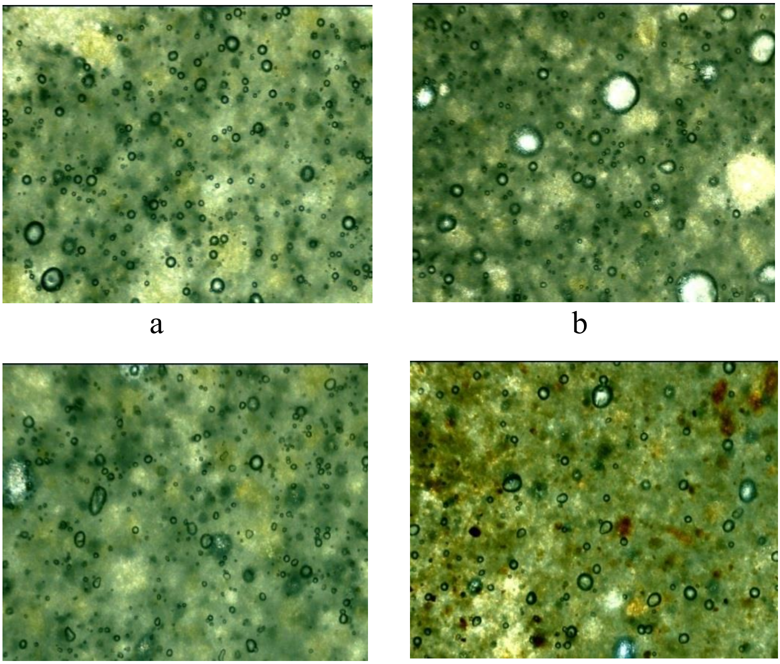

a b

c d

Fig. 3.4. Microstructure (× 300) of emulsions for shortcrust butter biscuits made with: a – margarine; b, c, d – a mixture of margarine and oil (b – without additives; c – with 15.0% CM; d – 15.0% WM)

The results of microscopy show that the addition of CM and WM ensures the uniform distribution of small fat globules, which have almost the same size, throughout the emulsion structure in a mixture of margarine and oil.

The positive influence of nut meals on the stability (Fig. 3.3) and dispersity (Table 3.4, Fig. 3.4) of the emulsion for shortcrust butter biscuits with the replacement of 30% margarine with sunflower oil can be explained by their high water-holding properties and good fat-holding and fat-emulsifying capacities compared to liquid oils. Additionally, it is known that high-dispersion powders can act as solid emulsifiers (Pickering effect). In this case, powder particles are wetted by different sections of the emulsion's surface, concentrate at the interface, and protect fat droplets from coalescence with so-called shielding shells [245].

A key rheological characteristic of emulsions that determines their technological properties is the effective viscosity, which characterizes the degree of resistance to flow. The obtained curves of effective viscosity for the studied emulsion samples (Fig. 3.5) exhibit a typical appearance for non-Newtonian fluids.

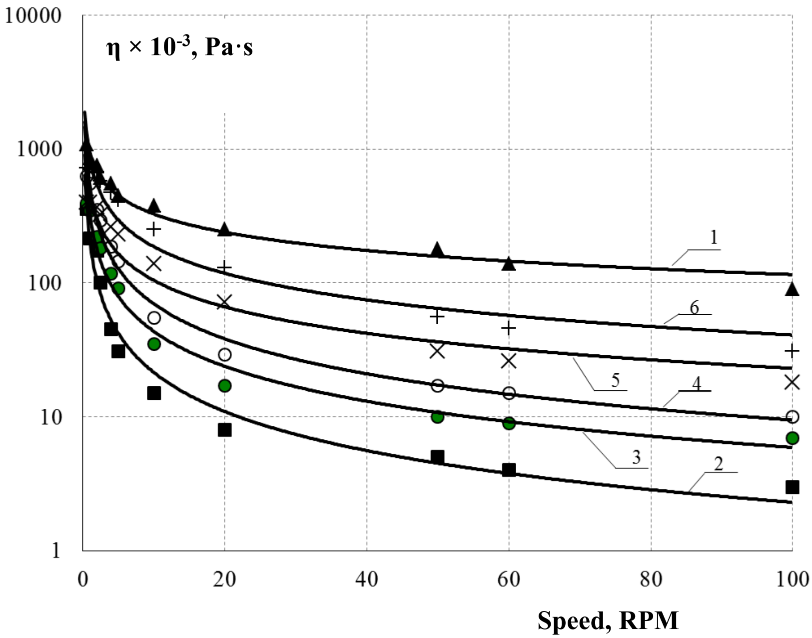

Fig. 3.5. Effective viscosity of the investigated emulsion samples: 1 – on margarine; 2, 3, 4, 5, 6 – on a mixture of margarine and oil (2 – without additives; 3 – with 10% CM; 4 – with 10% WM; 5 – with 15% CM; 6 – with 15% WM).

These fluids are characterized by a decrease in the value of effective viscosity with increasing shear rate. From the graph, it can be seen that the zone of avalanche destruction of the structure in samples with meal occurs at higher shear rate values than in the sample with sunflower oil at the same shear rate. The observed effect can be explained by the presence of dietary fibers in the additives and the formation of a new dispersed system – emulsion suspension. It is established that the consistency coefficient of the emulsion with the replacement of 30% margarine with sunflower oil decreases by 4.6 times with an increase in the rate of structure destruction by 2.1 times compared to the control on margarine basis (Table 3.5).

Table 3.5 – **Consistency coefficient and rate of structure destruction for investigated emulsion samples**

Sample	Consistency Coefficient (B), Pa·s	Rate of structure destruction (m), revolutions per minute
On margarine	0.92	0.45
On a mixture of margarine and oil		
Without additives	0.20	0.97
With 10% CM	0.32	0.87
With 10% WM	0.51	0.86
With 15% CM	0.49	0.67
With 15% WM	0.85	0.66

In the case of adding 10% CM or WM, this indicator increases by 1.6 and 2.4 times, respectively. Increasing the amount of meal to 15% leads to an increase in the consistency coefficient by 2.6 and 4.2 times, respectively.

For an emulsion with partial replacement of margarine with sunflower oil, the structure disruption rate is 0.97. The introduction of CM, regardless of its quantity, reduces this indicator by 10%. The addition of WM leads to a 30% decrease in the structure disruption rate.

It is noted that WM, compared to CM, more significantly slows down the rate of structure disruption in the emulsion on a mixture of margarine and oil. This confirms the earlier obtained results of emulsion stability research and is explained by the specific composition of biopolymers in the additives. Thus, the use of nut meal (CM, WM) increases the viscosity of the emulsion for butter biscuits with the addition of liquid oils, making it more resistant to disruption.

In summary, it can be recommended to improve the properties of emulsion for butter biscuits with liquid oils by adding up to 15% of cedar or walnut meal.

It is well known that the quality of butter biscuits depends not only on the quality of the emulsion but also on the quality of the dough. Therefore, it is necessary to study the influence of nut meals on the characteristics of the dough for sand butter biscuits with the addition of liquid oils.

3.3. Determining the structural and mechanical properties of dough for butter cookies with nut meal

Significant roles in the formation of sand butter biscuits are played by its rheological characteristics, particularly adhesive strength and resistance to disruption.

The adhesive strength indicator characterizes the interaction of the dough with the material of technological equipment – working elements of machines and apparatuses, surfaces of dispensing containers, screws, etc. Monitoring this indicator is particularly important during mechanized forming.

The production of cookies using the molding method usually occurs on rotary-type machines, in which case the adhesion of the dough to the rotor surface should be minimal, and to the tape of the receiving conveyor – maximal. An increase in the adhesive strength of sand dough can lead to its sticking to the working elements of the equipment and sticking in the molds during forming. A reduction in adhesion results in a weakened contact of blanks with the surface of the conveyor, and as a result, cookie blanks may also remain in the molds. In this case, there is a need for additional manual labor, increased consumption of food raw materials, and worsened sanitary conditions in production. Therefore, it is advisable to analyze changes in the adhesive properties of sand dough with the use of experimental additives.

Samples of dough made based on the following emulsions were subjected to investigation: on margarine (recipe No. 160, "Recipes for cookies, galettes, and wafers"), on a mixture of margarine and oil (with the substitution of 30% of margarine with refined deodorized sunflower oil) without additives, and on a mixture of margarine and oil with the addition of CM or WM in the amount of 10 and 15% of the total mass of recipe components for cookies. During the addition of additives, the dosage of flour was correspondingly reduced.

It is noted that the substitution of 30% of margarine with sunflower oil leads to an increase in the dough adhesion indicator by 16.8% (Table 3.6).

The adhesive properties of the dough are primarily determined by the ability of the gluten proteins in the flour to absorb moisture during dough kneading, causing them to extend beyond the limits of the starch gap in the form of strands and films, sticking together and gaining the ability to form adhesive bonds with solid surfaces. It is known that fats can adsorb on the surface of flour biopolymers, preventing them from swelling.

Table 3.6 – **Dough adhesion strength for shortcrust butter biscuits with different content of CM and WM**

($p \leq 0{,}05$, $n=5$, $\sigma=3...5\%$)

Dough sample	Adhesion strength, Pa
On margarine	420.2
On a mixture of margarine and oil	
Without additives	490.7
With 10% CM	473.6
With 10% WM	468.3
With 15% CM	447.2
With 15% WM	434.8

However, the degree of interaction between fats and dough components depends on the degree of their emulsification. Considering that the emulsion dispersion in margarine is higher than in the emulsion of a mixture of margarine and oil (Table 3.4), fat better blocks the interaction of flour biopolymers with water, allowing the dough to achieve a lower adhesive stress value.

It is noted that the addition of nut meals to sandy dough with the addition of liquid oil leads to a decrease in the adhesion index. This can be explained by several factors. Firstly, in the presence of nut meals, the dispersion and uniformity of emulsions improve, facilitating better contact between fat droplets and the biopolymers of flour, and restricting the swelling of the latter. Secondly, nut meals are characterized by high water-holding capacity, resulting in competition with flour particles for moisture absorption and leading to a reduction in the amount of free moisture in the dough. Considering that WM is characterized by higher water-holding and fat-emulsifying properties compared to CM, its impact on the adhesion strength indicator of the dough in the margarine and oil mixture is more pronounced. Thirdly, in systems with the addition of nut meals, the recipe content of flour decreases, i.e., the proportion of components responsible for creating adhesive bonds decreases. It should be noted that dough samples with the addition of 15% CM and WM are closest to the control sample in terms of adhesion strength (447.2 and 434.8 Pa, respectively, compared to 420.5 Pa in the control). Therefore, the use of nut meals will not require additional adjustment of the technological line for the production of sandy-extruded puff butter biscuits.

The structural-mechanical properties of the dough were assessed based on the penetration degree indicator (Table 3.7), which reflects the depth of immersion of the conical indenter of the penetrometer into the tested sample.

Table 3.7 – **Dough penetration indicators for puff butter biscuits with the addition of nut meals**

($p \leq 0{,}05$, $n=5$, $\sigma=3...5\%$)

Dough sample	Penetration indicator, instrument units
On margarine	99
On a mixture of margarine and oil	
Without additives	92
With 10% CM	88
With 10% WM	84
With 15% CM	77
With 15% WM	69

The table shows that, when replacing part of the margarine with sunflower oil, there is a decrease in the dough penetration indicator, indicating an increase in its strength. Specifically, the dough made from a mixture of margarine and oil has a penetration degree indicator value 7.1% lower compared to the control with only margarine.

The addition of nut meals tends to further reduce the value of this indicator. More pronounced changes in penetration degree are characteristic of dough samples with the addition of WM (Walnut Meal), which may be attributed to its better water-holding and fat-holding properties. Visually, this is accompanied by an increase in dough crumbliness, which can affect the quality of the forming operation.

The shaping of the puff butter biscuits is mainly carried out on rotary-type machines, capable of forming dough with a wide range of structural-mechanical properties. Therefore, changes in the dough penetration indicator with nut meals are not crucial in terms of maintaining the desired form.

3.4. The influence of nut meal on the physicochemical and sensory parameters of butter cookies with liquid oils

The quality assessment of the finished cookies was conducted based on physico-chemical (alkalinity, moisture content, water absorption, strength) and organoleptic indicators (shape, surface, color, taste and smell, appearance on breakage) according to DSTU (State Standard of Ukraine). The research objects were cookie samples obtained from the dough samples discussed in section 3.3. The cookies were formed using the extrusion method. The temperature and duration of baking for samples with different additive contents were fixed values ($t = 200...205^{o}C$, ($\tau = 10...12 \cdot 60$ s).

According to the normative documentation, the moisture content of cookies made according to the selected control recipe should be 5.5±1.5%. According to the experiment results, all investigated samples meet the established moisture content requirements (Table 3.8).

Table 3.8 – **Physico-chemical indicators of puff butter biscuits with the addition of nut meals**

($p \leq 0,05$, n=5, σ=3...5%)

Indicator	Dough samples					
	On mar-gari ne	On mar-garine and oil	On margarine and oil with nut meal, % of total recipe components mass			
			10% CM	10% WM	15% CM	15% WM
Moisture, %	4.2	5.9	5.3	5.5	4.6	4.9
Water Absorptio, %	160.0	175.3	178.2	187.4	196.6	204.8
Alkalinity, grad	1.61	1.60	1.41	1.27	0.99	0.82
Strength, × 10^3, Pa	320	333	345	340	362	355

It is noted that cookies made with the addition of sunflower oil, compared to cookies with margarine, are characterized by higher moisture content. This is explained by the high mobility and poor emulsification of sunflower oil during baking, leading to fat migration. As a result, a fat film forms on the surface of the cookies, preventing moisture evaporation during baking.

From Table 3.8, it can be seen that the addition of nut meals to cookies with a mixture of margarine and oil results in a slight decrease in moisture content, approaching the value of the control sample. This is likely due to several factors. Firstly, the additives bind sunflower oil, slowing its migration, which, in turn, increases moisture evaporation. Secondly, at temperatures of 90ºC and above (Fig.2.15, Section 2), starch in flour plays a significant role in moisture retention, rather than nut meals. The introduction of nut meals reduced the recipe content of flour, leading to a slight decrease in cookie moisture with additives.

Critical qualitative characteristics of puff butter biscuits include its structural-mechanical properties, which are determined by water absorption and strength indicators. Water absorption reflects the ability of cookies to absorb moisture, depending on their porosity and physico-chemical properties. The water absorption indicator values (Table 3.8) for all investigated cookie samples are above 110%, meeting the requirements of DSTU 3781. It is noted that the sample made with a mixture of margarine and oil surpasses the control by 9.4% in terms of this indicator. This is due to sunflower oil forming larger droplets in the emulsion than margarine, resulting in larger pores during baking and increased water absorption capacity.

To assess the consumer properties of cookies (crispness) and their resistance to external forces during transportation, the strength indicator of the cookies is determined, which somewhat characterizes the degree of crumbliness. As seen from Table 3.8, the strength of cookies with a mixture of margarine and oil is somewhat increased compared to the control with margarine. The addition of up to 15% CM and WM to such cookies leads to an increase in this indicator by 13.1% and 10.9%, respectively, compared to the margarine control and by 8.7% and 6.7%, respectively, compared to the oil sample without additives. The increase in cookie strength can be explained by the strengthening effect of nut meals on the gluten of wheat flour and the formation of lipid complexes between liquid oil and dough components, thanks to its high mobility compared to solid fat.

Research on the alkalinity of the finished products showed that with an increase in the dosage of CM and WM, the alkalinity value slightly decreases. This can be explained by the presence of a certain amount of free fatty acids in sunflower oil and organic acids in nut meals, which neutralize the alkaline environment of the dough. It is noted that, in terms of alkalinity, all investigated samples meet the requirements of DSTU 3781–2014 – not exceeding 2.0 degrees.

In addition to physico-chemical quality indicators, organoleptic properties of the product are essential consumer characteristics (Table 3.9).

Cookies with the addition of sunflower oil hardly differ in taste characteristics from cookies made with margarine. However, it is characteristic for them to deteriorate in shape (becoming more spread out), the surface slightly cracks, and becomes oily, and porosity worsens – large cavities appear. The addition of nut meal allows correcting these defects. Samples with an additive content of 15% by the main organoleptic characteristics almost do not differ from the control. They only show a slight change in color – pale brown in the sample with WM and saturated cream in the cookie with CM. Also, the products acquire a pleasant nutty taste and aroma, and are characterized by a more pronounced sweetness, which is caused by the presence of mono- and oligosaccharides in the meal. In our opinion, this fact is a reason to regulate the sugar content during the development of recipes for cookies with these additives.

Table 3.9 – **organoleptic indicators of the investigated cookie samples**

Indicator	Dough samples					
	On margarine	On margarine and oil	On margarine			
			10% CM	10% WM	15% CM	15% WM
Form	Regular, even edges	Spread, slightly deformed	Spread, slightly deformed		Regular, even edges	
Surface	Smooth, not burnt, crack-free	Smooth, not burnt, slightly oily, with a few cracks	Smooth, not burnt, crack-free, slightly oily, with a few cracks		Smooth, not burnt, with a few cracks	
Color	Pale yellow	Pale yellow	Pale yellow	Creamy	Creamy	Pale brown
Taste and Smell	Corresponding to the product type, without foreign elements		Corresponding to the product type, without foreign elements		Corresponding to the product type, without foreign elements, with a pleasant nutty taste and aroma, and more pronounced sweetness	
Break appearance	Baked cookies, uniform porosity, without signs of impurity mixing	Baked cookies, porosity somewhat uneven, without signs of impurity mixing	Baked cookies, porosity somewhat uneven, without signs of impurity mixing		Baked cookies, uniform porosity, without signs of impurity mixing	

Conclusions from Chapter 3

1. Walnut meal reduces the yield and hydration capacity of flour gluten and, at the same time, has a strengthening effect, manifested in certain changes in the physical and structural-mechanical properties of the dough – its stability decreases,

and the degree of dilution under the influence of mechanical processing increases. SHM has a greater impact on flour gluten.

2. The addition of walnut meal in an amount of 20% of the total mass of ingredients for cookies, with an emulsion replacing 30% of margarine with sunflower oil, results in a high viscosity that prevents achieving the typical structure of puff butter biscuits. This limitation justifies restricting the dosage of additives to 15%.

3. The stability of the emulsion for cookies with a mixture of margarine and oil is 37.5% lower compared to the control. The addition of 15% CM and WM contributes to improving the stability of such emulsion by 48% and 56%, respectively. WM, compared to CM, more significantly slows down the rate of emulsion structure breakdown with the addition of liquid oil.

4. Substituting 30% of margarine with sunflower oil increases dough adhesion for cookies by 16.8%, while incorporating up to 15% walnut meal into this system allows reducing this parameter, bringing it closer to the control. Thus, the use of walnut meal will not require additional adjustment of the cookie manufacturing line.

5. When partially replacing margarine with sunflower oil, the dough penetration level decreases by 7.1%. The addition of walnut meal further contributes to reducing this parameter, justifying its formation by the "well" method.

6. The use of walnut meal in shortbread puff butter biscuits with sunflower oil meets the requirements of regulatory documentation in terms of physicochemical indicators (moisture, water absorption, alkalinity, and strength) and organoleptic characteristics. There is an enhancement of the sweet taste in cookies with walnut meal, allowing a reduction in the recipe sugar content.

CHAPTER 4
DEVELOPMENT OF THE TECHNOLOGY OF BUTTER COOKIES WITH THE ADDITION OF LIQUID OILS AND NUT MEAL

4.1. Optimizing the recipe for butter shortbread cookies with the addition of liquid oils and nut meal

Optimizing the recipe involves determining the proportion of recipe components that will ensure the best product quality in terms of compliance with defined quality indicators in regulatory documentation. One of the indicators that significantly reflects the consumer properties of cookies and is regulated by DSTU is the soaking capacity, selected as the optimization parameter (y). Based on the results of previous studies, it was deemed appropriate to vary the amount of the corresponding nut meal (x_1), refined deodorized sunflower oil (x_2), and powdered sugar (x_3) in the recipe. The dosages of other raw materials, as well as the parameters of technological processes (beating duration, kneading, baking, baking temperature), were kept consistent with traditional technology. Planning and conducting the research were carried out using an incomplete factorial experiment scheme 3^3.

To construct the experiment matrix, values for the zero level of the investigated variability factors were selected at the first stage:

x_1 – 15.0% of the total mass of recipe components;

x_2 – 30.0% of the margarine mass;

x_3 – 17.9% of the total mass of recipe components.

The choice of zero-level values for nut meal and sunflower oil is justified by the results of experiments in previous sections, while the zero level for powdered sugar is based on its recipe dosage in the control formulation.

As a result of implementing the experiment matrix, the following outcomes were obtained (Table 4.1–4.2).

The calculated criterion Cochran's value, obtained through variance, does not exceed the tabulated value:

– For cookies with WHC – 0.27 (G_p) < 0.3264 (G_T),

– For cookies with CM – 0.246 (G_p) < 0.3264 (G_T).

This indicates homogeneity of variances, implying the consideration of all factors influencing the process of obtaining sponge cookies.

To describe this experiment, the following model is used:

$$Y(x_1, x_2, x_3) = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_1^2 + a_5x_2^2 + \\ + a_6x_3^2 + a_7x_1x_2 + a_8x_2x_3 + a_9x_1x_3 + +a_{10}x_1x_2x_3, \quad (4.1)$$

Where $Y(x_1, x_2, x_3)$ – is the soaking capacity function;

$a_0, a_1 \ldots a_{10}$ – are unknown coefficients.

Table 4.1 – **Results of implementing the experimental matrix for cookies with the addition of WM**

№	Level of variability factor			Soaking capacity, %				S^2
	x_1	x_2	x_3	y_1	y_2	y_3	y_{cp}	
1	13	25	12.9	147.4	148.7	147.9	148	0.5
2	17	25	12.9	143.4	147.0	145.1	145.1	3.3
3	13	35	12.9	169.9	172.8	171.3	171.3	2.0
4	17	35	12.9	188.7	188.4	186.2	187.8	1.8
5	13	25	22.9	132.1	134.9	133.5	133.5	1.9
6	9	25	22.9	132.8	130.5	132.9	132.1	1.8
7	13	35	22.9	174.3	170.0	175.4	173.3	8.1
8	9	35	22.9	149.1	149.1	152.6	150.3	4.0
9	15	30	17.9	194.5	192.7	193.6	193.6	0.9
10	11	40	17.9	152.6	151.2	152.4	152.1	0.5
11	11	30	17.9	182.0	185.3	182.3	183.2	3.2
12	9	40	17.9	125.9	125.4	123.2	124.9	2.1

Table 4.2 – **Results of implementing the experimental matrix for cookies with the addition of CM**

№	Level of variability factor			Soaking capacity, %				S^2
	x_1	x_2	x_3	y_1	y_2	y_3	y_{cp}	
1	13	25	12.9	180.3	182.0	186.0	182.8	8.6
2	17	25	12.9	183.0	176.1	178.6	179.2	12
3	13	35	12.9	181.3	179.9	177.9	179.7	2.9
4	17	35	12.9	201.6	198.3	197.0	198.9	5.5
5	13	25	22.9	157.0	160.0	156.4	157.8	3.7
6	9	25	22.9	156.6	153.1	155.3	155.0	3.2
7	13	35	22.9	170.9	172.7	168.3	170.7	4.8
8	9	35	22.9	150.4	148.8	148.6	149.3	0.9
9	15	30	17.9	206.3	200.0	207.7	204.7	16.9
10	11	40	17.9	143.1	141.1	144.4	142.8	2.7
11	11	30	17.9	191.9	191.6	195.3	192.9	4.2
12	9	40	17.9	117.6	121.2	119.1	119.3	3.3

To obtain the coefficients $a_0, a_1 \dots a_{10}$, the method of least squares is applied. A functional is formulated, the minimization of which will allow finding the values of these coefficients:

$$J=\sum_{i=1}^{12} (Y(x_{1i}, x_{2i}, x_{3i}) - \bar{y}_i)^2, \quad (4.2)$$

Where:

x_{1i} – the value of the nut meal fraction for the i-th experiment

x_{2i} – the value of the fat fraction for the i-th experiment

x_{3i} – the value of the powdered sugar fraction for the i-th experiment

$\bar{y}_i$ – the average value of the soaking capacity

Minimizing functional 4.2 was implemented as follows. Finding partial derivatives of functional 5.2 with respect to unknown coefficients a_0, a_1 .... a_{10} and setting them equal to zero gives a system of linear algebraic equations, consisting of eleven equations with eleven unknowns. Solving this system was implemented in the MatCad program and allowed obtaining the equation describing the dependence of soaking capacity on the dosage of nut meal, liquid oil, and powdered sugar:

– For cookies with CM

$$y = -558 + 19{,}9x_1 + 24{,}4x_2 + 30{,}5x_3 - 0{,}742x_1^2 - 0{,}511x_2^2 - 0{,}743x_3^2 + 0{,}387x_1x_2 + 0{,}0587x_2x_3 - 0{,}735x_1x_3 + 0{,}00539x_1x_2x_3;$$

– For cookies with WM

$$y = -767 + 28{,}3x_1 + 26{,}7x_2 + 37{,}9x_3 - 1{,}01x_1^2 - 0{,}528x_2^2 - 0{,}909x_3^2 + 0{,}408x_1x_2 + 0{,}0904x_2x_3 - 0{,}0848x_1x_3 + 0{,}00576x_1x_2x_3.$$

The next step was to find the optimal values of the soaking capacity, at which the function 4.1 reaches its maximum. Since the function is a polynomial, the maximum of such a function is typically found by equating the derivatives with respect to the factors x_1, x_2, x_3 to zero and solving the resulting system of three equations with three unknowns. In our research, the Mathcad program was used, and a standard procedure was applied to determine the maximum. The implementation of this procedure yielded the following optimal values for the investigated variability factors (Table 4.3).

The conducted optimization served as the basis for developing two new recipes for shortcrust sandy sponge cookies with the addition of CM and WM.

Table 4.3 – **Results of optimizing the ratio of recipe components for cookies with nut meal**

For sponge cookies	Dosage of respective component			Value of the optimization parameter (soaking capacity, %)
	Nut meal, % of total mass of recipe components	Sunflower oil, % of margarine mass	Powdered sugar, % of total mass of recipe components	
With CM	15.8	32.2	15.8	210
With WM	15.3	34.1	17.0	203

4.2. Development of recipes for butter shortbread cookies with liquid oil and nut meal and improvement of the technological scheme of its production

Based on the conducted calculations to determine the optimal dosages of recipe components, two recipes for shortcrust sandy sponge cookies with a mixture of margarine and sunflower oil and the addition of nut meal (Table 4.4) are proposed. To ensure the dry matter content similar to the control sample, the flour content was reduced during the calculation.

A technological scheme for producing new types of cookies has been proposed, which differs from existing ones in that, at the stage of obtaining the emulsion, refined deodorized sunflower oil and walnut meal are additionally introduced. The introduction of walnut meal at the specified stage is justified by its high fat-holding and fat-emulsifying properties.

Table 4.4 – **Recipes for shortcrust sandy sponge cookies with a mixture of margarine and oil with the addition of nut meal**

Raw materials	Mass fraction of dry matter, %	Raw material consumption per 1000 kg of finished product, kg			
		Cookies with CM		Cookies with WM*	
		In kind, kg	In dry matter, %	In kind, kg	In dry matter, %
Wheat flour of the highest grade	85.50	349.59	298.90	338.92	289.78
Powdered sugar	99.85	193.58	193.29	208.29	207.97
Margarine	84.00	222.63	187.01	216.39	181.77
Refined deodorized sunflower oil	99.90	105.73	105.63	111.97	111.86
Melange	27.00	98.51	26.60	98.51	26.60
Vanilla powder	99.85	3.69	3.68	3.69	3.68
Ammonium bicarbonate	0.00	1.09	0.00	1.09	0.00
Melange (for greasing)	27.00	27.36	7.39	27.36	7.39
CM	91.70	193.58	177.52	-	-
WM	91.20	-	-	187.46	170.96
TOTAL		**1195.76**	**1000.01**	**1193.68**	**1000.01**
OUTPUT	**95.30/ 95.05***	**1000.00**	**953.00**	**1000.00**	**950.50**

To justify the duration of this stage, a study of the mass multiplication dependence on the time of mechanical influence was conducted (Table 4.5). The mass multiplication was assessed based on the degree of volume increase of the mixture.

Table 4.5 – **Emulsion multiplicity depending on beating duration**

Duration of beating ($\tau \times 60^{-1}$), s	Mass multiplicity, units	
	With CM	With WM
5	1.12	1.13
7	1.44	1.43
9	1.47	1.49
11	1.49	1.51
13	1.49	1.51

It is noted that the type of meal almost does not affect the value of the studied indicator. It has been established that with the extension of beating from 11 to 13 minutes, there is no increase in mass in volume. Considering this, it is deemed reasonable to limit the duration of the emulsification stage (obtaining the emulsion) in the range of $(11.0 \pm 1.0) \times 60$ s (Fig. 4.1).

The hardware and technological scheme for the production of sand-dumping sponge cake with partial replacement of margarine with sunflower oil and the addition of nut meal is presented in Fig. 4.2.

To implement the developed technology, margarine is loaded into the mixing machine in a plasticized state, sunflower oil, powdered sugar, melange, leavening agents, flavorings, nut meal, and intensively mixed (emulsified) for 10...12 minutes until a homogeneous formulation mixture is formed. Flour is then added, and the dough is kneaded for 5...8 minutes at a temperature of 20...24ºC.

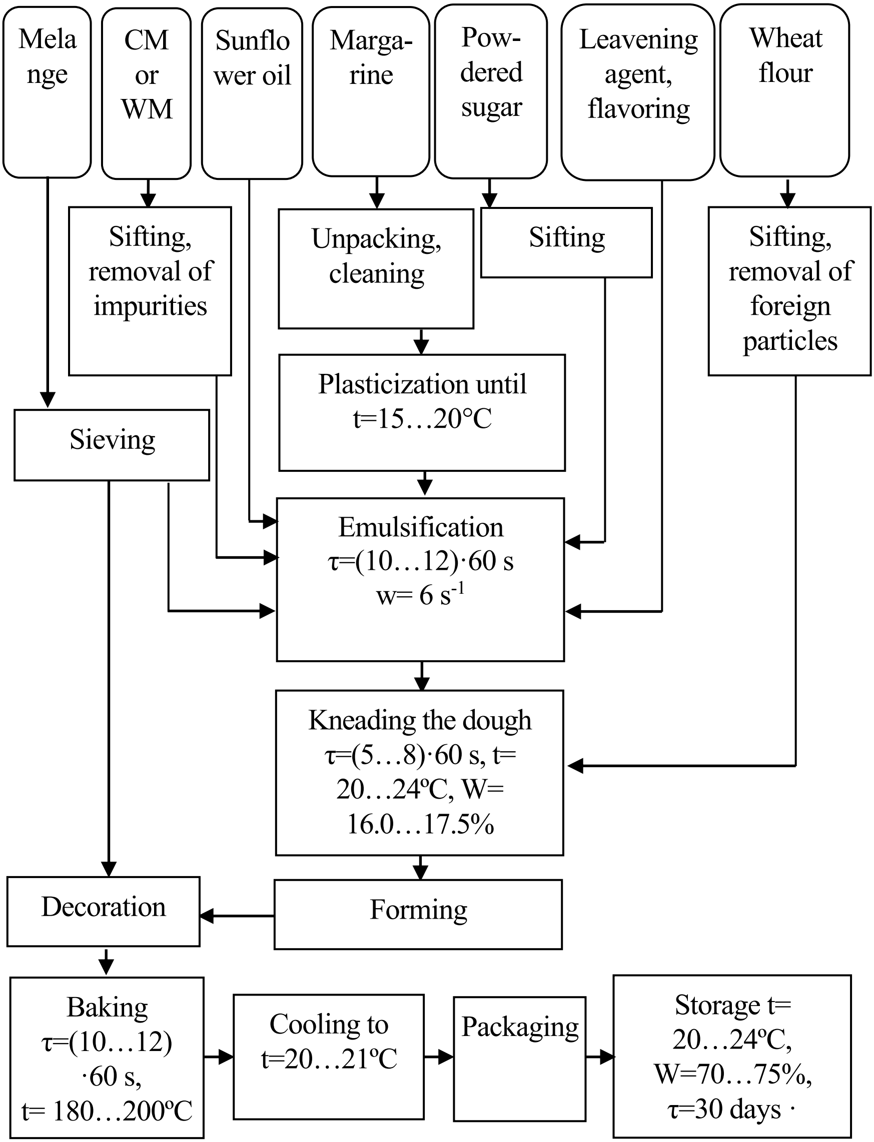

Fig. 4.1. Technological scheme of production of sand-biscuit pastries on a mixture of margarine and oil with nut cake

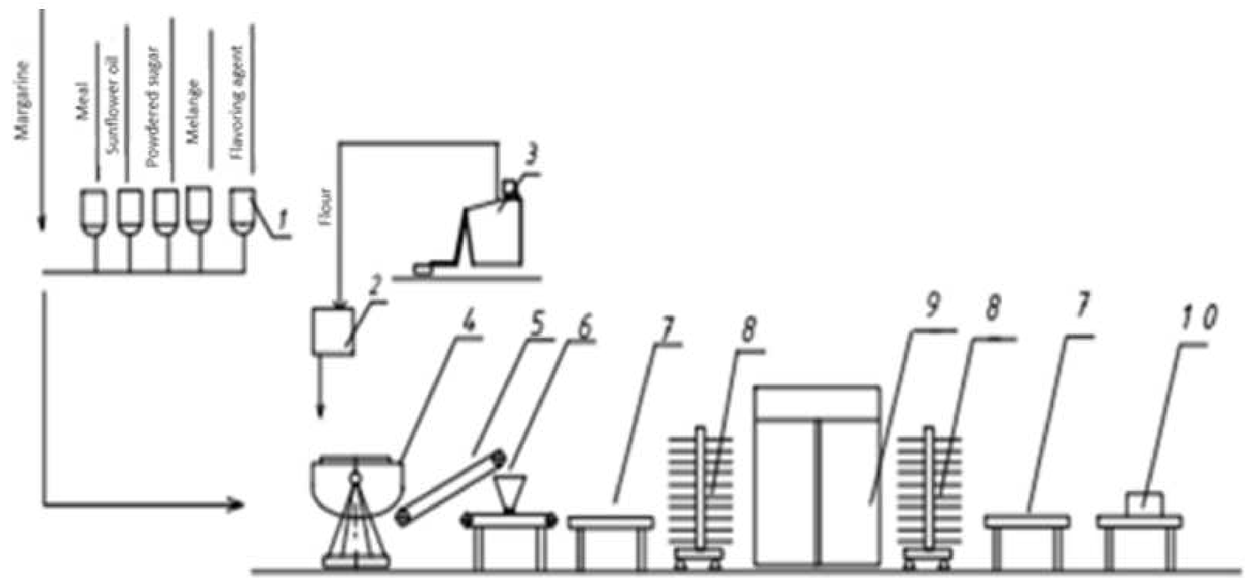

Fig. 4.2. Equipment and technological scheme of production of sand-cutting pastries on a mixture of margarine and oil with the addition of nut cake: 1 – containers for dosing raw materials; 2 – flour hopper; 3 – sifter; 4 – dough mixing machine; 5 – conveyor; 6 – rotary machine; 7 – table for decoration; 8 – trolley; 9 – rotary oven; 10 – packing table.

The obtained dough is formed on a rotary forming machine using a scooping method, coated with melange, and baked in continuous conveyor ovens or rotary ovens. The finished cookies are cooled, sent for packaging, and storage.

4.3 Analysis of nutritional and biological value of new types of cookies

The technology of sand-cutting pastries is proposed with the addition of CM in the amount of 15.8% and WM in the amount of 15.3% of the total mass of recipe components and with the replacement of 30% of margarine with sunflower oil. To identify the content of the main components of the chemical composition, the analysis of IR spectra of the developed samples of pastries was carried out (Fig. 4.3).

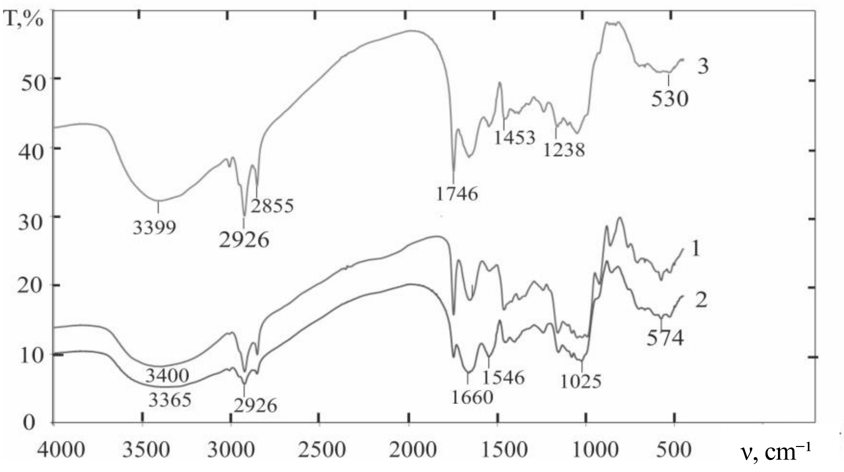

Fig. 4.3. IR spectra of the investigated samples of butter biscuits: 1 – without addition (control); 2 – with the addition of CM; 3 – with the addition of WM

The assignment of absorption bands of the samples is provided in section 2 (Table 2.2).

Analyzing the IR spectra of the butter biscuits samples with the addition of CM and WM, it should be noted that the absorption bands with a maximum at 2925, 1746 cm^{-1} for the sample of butter biscuits with WM are more intense than in the spectra of butter biscuits samples with CM and the control sample. These findings confirm the presence of a higher content of organic and polyunsaturated fatty acids.

It is worth noting that for the control sample, more intense absorption bands in the range of 1000…900 cm^{-1} are observed compared to the samples with CM and WM. This may be related to the presence of trans-isomers of fatty acids (due to a higher recipe content of margarine) [232]. The broad asymmetric band in the range of 3400…3300 cm^{-1} can be attributed to the hydroxyl groups of carbohydrates and organic acids, which is shifted to the low-frequency region compared to the hydroxyl groups of water.

For the butter biscuits samples with nut meal, a higher intensity of the mentioned absorption band is observed, which may indicate an increase in the carbohydrate and organic acid content compared to the control sample. Additionally, it can be suggested that butter biscuits with nut meal loses less moisture during baking, likely due to the specific polysaccharide composition.

It is important to note that both the control and investigated butter biscuits samples exhibit an intense band in the range of 530…570 cm^{-1}. This band is less intense for CM and WM as raw materials (see figures 4.4, 4.5) and is associated with the significant sucrose content in the butter biscuits.

Comparing the IR spectra of the butter biscuits samples with the addition of CM and the individual sample of the corresponding nut meal (CM) (see figure 4.4), it should be noted that the broad band in the range of 3600…3300 cm^{-1}, associated with the valence vibrations of the hydroxyl group ν (O–H), is more intense and wider for the butter biscuits with CM than in the nut meal sample. It is also shifted to the high-frequency region, indicating a higher content of carbohydrate groups and water in the butter biscuits sample with the supplement [227].

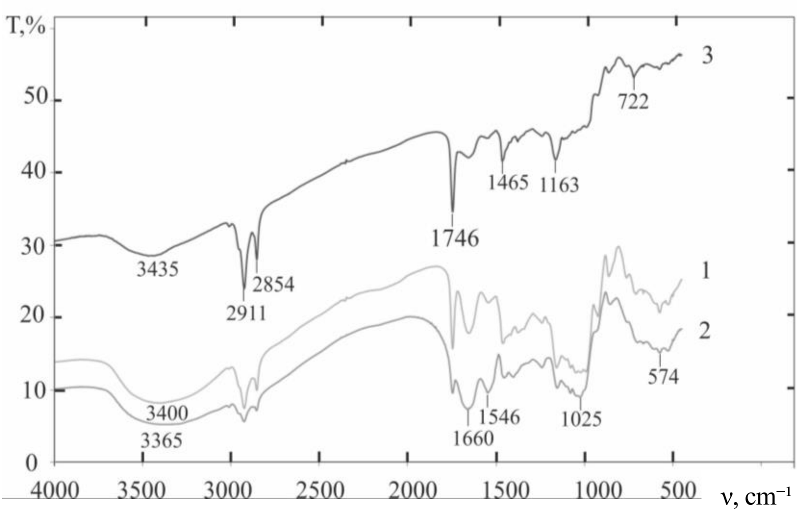

Fig. 4.4. IR spectra of butter biscuits sample with the addition of CM and CM sample: 1 – butter biscuits without the supplement (control); 2 – butter biscuits with CM; 3 – CM.

Comparing the IR spectra of the cookies with the addition of WHC and separately with the walnut meal (Fig. 4.5), it should be noted that the broad band ν(OH) in the range of 3600…3300 cm^{-1} for the sample of cookies with WHC is more intense and broader than in the meal. This indicates a higher content of carbohydrate groups and water in the cookie sample with the supplement [227]. Thus, the addition of the supplement contributes to an increase in the moisture content of the product.

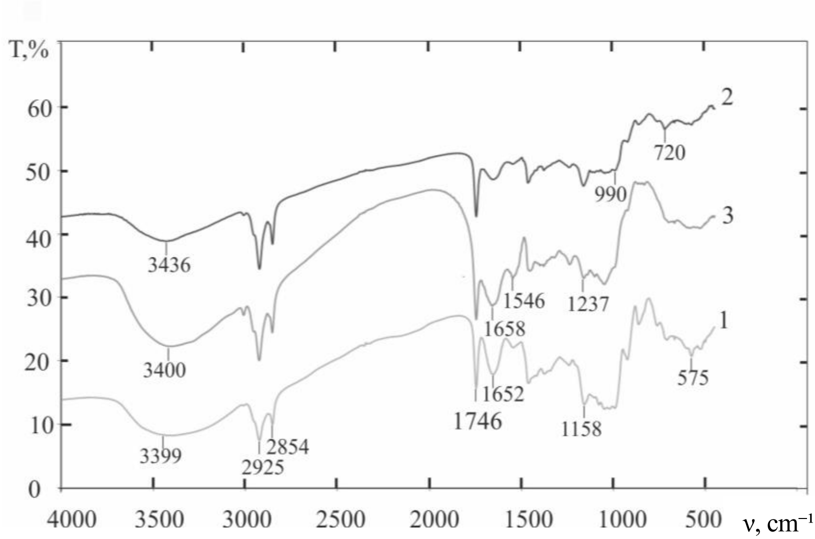

Fig. 4.5. IR spectra of the cookie sample with the addition of WM and the WM sample: 1 – cookie without the supplement (control); 2 – WM; 3 – cookie with WM.

It is worth noting that the vibration bands with absorption maxima at 1655 cm^{-1} and 1546 cm^{-1} in the control cookie sample and the cookie with WM are more intense than in the WM sample. This may be associated with a higher content of proteins and polypeptides. In the region of 1100…1000 cm^{-1} and 700…500 cm^{-1} in the spectra of the cookie sample with the addition of meal, absorption bands are more intense than in the meal sample but less intense than in the control sample. This is consistent with the previous study and is attributed to a significantly higher sucrose content in the cookie compared to the meal.

Thus, the analysis of IR spectra confirms that the use of walnut and cedar meal in butter biscuits technologies will significantly improve its nutritional composition by increasing the content of protein substances, organic acids, polyunsaturated fatty acids, phenolic, and pectin substances.

For the assessment of the beneficial properties, quantitative determination of the nutritional and energy value, as well as the content of physiologically valuable nutrients (vitamins, minerals, dietary fibers, polyunsaturated fatty acids (PUFA)), was conducted for the new types of cookies (Table 4.6). During the calculations, the "Norms of physiological needs of the population of Ukraine for basic nutrients and energy," approved by the Ministry of Health of Ukraine for women in the age group of 18–29 years of work intensity group I, were used [253].

It has been established that compared to the control, cookies made with a blend of margarine and sunflower oil with the addition of CM and WM contain approximately 1.8 and 1.6 times more protein, characterized by 14.7% and 12.8% lower carbohydrate content (due to a reduction in the recipe amount of sugar and flour), and significantly enriched with non-starch polysaccharides (4.7 and 2.9 times, respectively). The developed cookies have a slightly higher fat content, but at the same time, their fatty acid composition is significantly improved.

The calculations indicate that the integral score for PUFA in cookies with CM and WM exceeds the control sample by 2.5 and 2.8 times, respectively. The ratio of omega-3 to omega-6 fatty acids also improves. In particular, in cookies without additives, this ratio is 1 : 93, in cookies with CM – 1 : 12, and in cookies with WM – 1 : 18. The increase in protein and fat content in cookies with meal results in a slight increase in its energy value, which is insignificant and amounts to 1.7 and 3.7%, respectively.

It is important to note the enrichment of cookies with polyphenols. The integral score for this indicator in the developed samples is 127.31 and 387.75%.

Table 4.6 – **Chemical composition of nut-containing butter biscuits**

Nutrient Name	Daily requirement	Plain cookies (Control)		Cookies with a blend of margarine and oil with additives			
				CM		WM	
		Content per 100 g of the product	Total score, %	Content per 100 g of the product	Total score, %	Content per 100 g of the product	Total score, %
Protein, g	55	7.21	13.11	13.04	23.70	11.14	20.25
Fat, g	56	28.24	50.42	30.51	54.47	32.00	57.15
Including PUFA, g:	11	3.67	33.39	9.20	83.60	10.16	92.37
Linoleic (ω-6), g	10	3.62	36.25	8.51	85.10	9.60	95.99
Linolenic (ω-3), g	1	0.04	3.90	0.69	68.62	0.54	54.24
Carbohydrates, g	320	59.50	18.60	50.75	15.86	51.91	16.22
Including non-starch polysaccharides, g	20	0.86	4.29	4.00	20.01	2.52	12.59
Polyphenols, mg	200	0.00	0.00	254.61	127.31	775.50	387.75
Energy value, kcal	2450	521.00	21.26	529.75	21.62	540.20	22.05
Vitamins, mg							
E	15	3.43	22.86	10.04	66.90	11.14	20.25
B_1	1.4	0.15	10.44	0.24	17.02	32.00	57.15
B_2	1.6	0.08	4.87	0.10	6.55	10.16	92.37
B_5	6	0.32	5.36	0.47	7.78	9.60	95.99
Mineral substances, mg							
Iron	15	0.64	4.29	1.25	8.32	2.93	19.57
Potassium	2000	85.43	4.27	295.73	14.79	226.31	11.32
Calcium	1000	19.87	1.99	18.94	1.89	64.87	6.49
Silicon	25	2.13	8.54	1.35	5.41	17.66	70.63
Magnesium	400	10.33	2.58	78.01	19.50	56.87	14.22
Manganese	3	1.49	49.69	4.44	148.03	3.01	100.41
Copper	1	0.26	26.31	1.00	100.07	0.58	58.12
Phosphorus	800	74.48	9.31	114.97	14.37	84.98	10.62
Zinc	12	1.07	8.93	5.28	44.00	3.21	26.72

A special role among food components is attributed to vitamins and minerals. The cookies are made from refined products (sugar, margarine, wheat flour). The inclusion of CM and WM in its formulation will significantly increase the content of vitamin E (almost threefold), iron (2.0 and 4.6 times), potassium (3.5 and 2.6 times), magnesium (7.6 and 5.5 times), manganese (3.0 and 2.0 times), and copper (3.8 and 2.2 times), bringing the values of the integral score for these substances closer to physiologically significant levels. Cookies with WM slightly lag behind cookies with CM in terms of potassium, magnesium, manganese, and copper content, but significantly surpass them in iron, calcium, and silicon content.

Thus, the use of CM and WM in the technology of making cookies allows for the enrichment of the products with protein, non-starch polysaccharides, PUFA, polyphenols, minerals, and vitamin E.

4.4. Evaluation of the quality of new products during storage

During the storage of cookies, changes in its quality indicators occur. The aim of this series of studies was to determine the compliance of the developed types of cookies with a blend of margarine and oil with the addition of CM and WM with the requirements of regulatory documentation at the end of the storage period. According to DSTU 3781:2014, cookies with a fat content of over 20% should maintain their quality characteristics at a certain level for 30 days.

The objects of the study were samples of cookies made with margarine, a blend of margarine and oil, a blend of margarine and oil with the addition of CM, and a blend of margarine and oil with the addition of WM. The preparation of experimental samples was carried out according to Table 4.4 and Fig. 4.3.

The samples were stored in plastic packaging at a temperature of 18±3ºC and relative humidity of 75% for 35 days, corresponding to the storage duration of shortbread cookies according to DSTU. The research was conducted in three main directions: evaluation of the state of the lipid complex of products, organoleptic indicators, and microbiological stability.

During storage, the most significant changes in cookies occur in the state of its lipid complex, which is due to the high proportion of the fat component in the recipe [254]. Taking this into account, the quality of cookies during storage was assessed by indicators that characterize the properties of the lipid complex (degree of fat migration, acid number, peroxide number), and organoleptic characteristics. Control of the degree of fat migration and organoleptic indicators was carried out immediately after baking and at the end of storage (after 35 days). Samples for evaluating the acid and peroxide numbers were collected every 7 days. Extraction of fat from the samples was carried out by the extraction-weighing method.

It is known that the inclusion of liquid oils in the cookie recipe is limited because they poorly adhere to the dough and finished products and can be released from them during storage. Therefore, at the first stage, the degree of fat migration from the examined cookie samples was assessed (Fig. 4.6).

According to the data from the diagram, after 35 days of storage, cookies made with a blend of margarine and oil release 10.6 times more fat than the control sample. The addition of CM and WM slows down the degree of fat migration by 74.1% and 78.8% relative to the control, respectively. This effect of nut meals is due to the specific composition of their protein substances and polysaccharide complexes, which exhibit fat-holding properties.

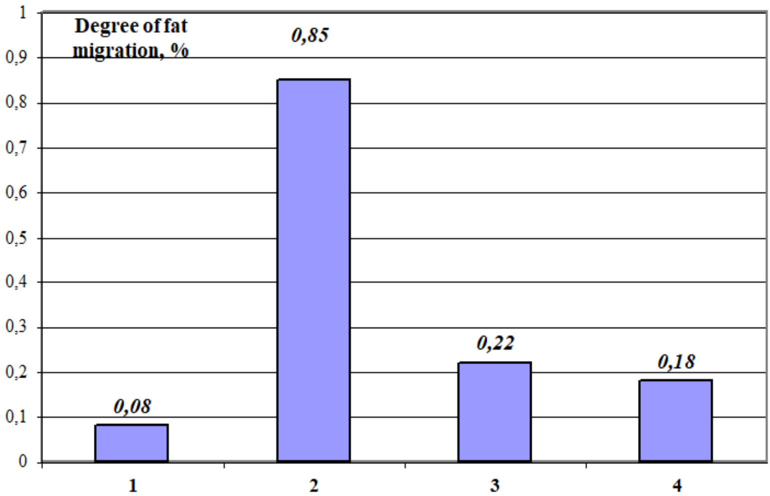

Fig. 4.6. Degree of fat migration (DFM) from the examined cookie samples after 35 days of storage: 1 – with margarine; 2, 3, 4 – with a blend of margarine and oil (2 – without additives; 3 – with CM; 4 – with WM).

The degree of oxidation of the lipid complex of cookies was assessed using indicators of acid and peroxide values.

The acid value indicator characterizes the presence of free fatty acids in the fats formed as a result of the hydrolysis of acylglycerols, which is accelerated with an increase in temperature and under the influence of enzymes. The inclusion of sunflower oil and nut meals in cookies creates conditions for hydrolytic processes. Specifically, the oil and nut meals contain hydrolytic enzymes (lipases) that become activated when the humidity of the environment exceeds 12% [246] (the dough's moisture content for cookies is approximately 20%) and within the temperature range of 30…50 ºC. Thus, at the beginning of baking, lipase becomes actively involved, leading to an increase in the acid value indicator of the lipid component of freshly baked samples with additives (Table 4.9).

Table 4.9 – **Changes in the acid value (mg KOH/g) of fats in the examined cookie samples during storage**

($p \leq 0{,}05$, $n=5$, $\sigma=3{,}0…5{,}0\%$)

Sample of cookies	Storage duration, days					
	0	7	14	21	28	35
On margarine	0,14	0,14	0,15	0,15	0,15	0,16
On a blend of margarine and oil						
Without additives	0,19	0,19	0,21	0,21	0,22	0,23
With CM	0,37	0,37	0,39	0,39	0,41	0,42
With WM	0,31	0,31	0,33	0,34	0,36	0,36

The accumulation of free fatty acids occurs more intensively in the lipid fraction of cookies with the addition of CM, which is due to its higher content of lipases compared to WM (1.3 times). During storage, the acid value indicators of all examined samples of cookies almost do not change (relative to their values immediately after baking). This is associated, firstly, with the inactivation of hydrolytic enzymes under the influence of baking temperatures, and secondly, the finished cookies have low moisture content – (5.0±1.5)%. It is noted that throughout the entire study period, the cookie samples, in terms of the acid value, comply with the requirements of regulatory documentation – they do not exceed the value of 2 mg KOH/g.

For systems with a high fat content and low moisture content, the course of oxidative processes during storage is more characteristic, leading to the formation of peroxide substances. For high-quality fat systems, the peroxide value should not exceed 10 mmol ½O/kg. It has been established that the lipid fractions of all examined cookie samples meet these requirements (Fig. 4.7).

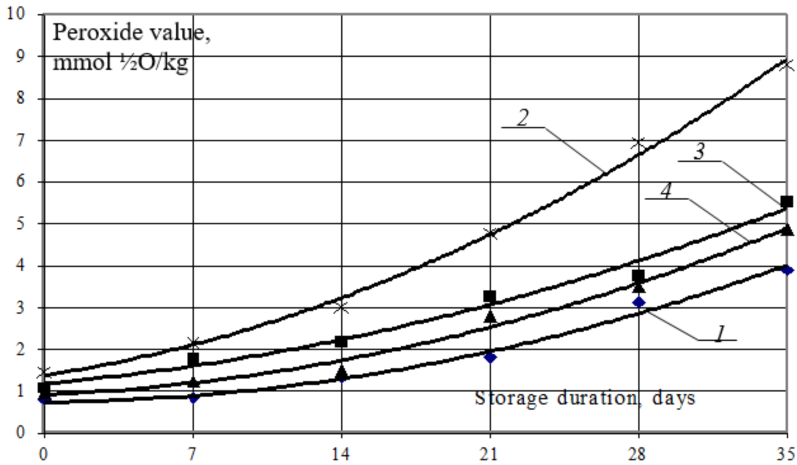

Fig. 4.7. Changes in the peroxide values of the fat in the examined cookie samples during storage: 1 – on margarine; 2, 3, 4 – on a blend of margarine and oil (2 – without additives; 3 – with CM; 4 – with WM).

It is known that the rate of oxidation of lipid substances depends on their fatty acid composition: fats containing a significant amount of unsaturated acyls oxidize faster. The oxidation process for unsaturated lipids begins with the formation of a free radical under the action of oxidation initiators. During further interaction with oxygen molecules, the formation of a peroxide radical occurs. Free peroxide radicals interact with other molecules of fatty acids, forming hydroperoxides and new radicals that initiate further oxidation of unsaturated fatty acids. It is noted that the least amount of peroxides over the entire evaluated storage period is characteristic of the lipid component of the control sample on a margarine basis. Despite the significant amount of unsaturated fats in margarine, the technological process of margarine production involves the addition of antioxidants, which prevents oxidative processes in cookies made with it.

The substitution of part of the margarine with sunflower oil accelerates the oxidation of the fat fraction in cookies due to the high content of polyunsaturated fatty acids in the oil. Immediately after baking, the peroxide value for the lipid component of the sample on the combined fat basis exceeds this value in the control by 1.8 times. After 35 days of storage, the peroxide value for the fats in cookies with a blend of margarine and oil increases by 6.4 times, reaching 8.9 mmol ½O/kg. In the control sample, over the same period, the increase in this indicator is 4.5 times.

It is noted that the cookies with CM and WM at the end of storage are characterized by a lower peroxide value compared to cookies on a blend of margarine and oil without additives - by 37.1% and 45.1%, respectively. The inhibitory effect of nut meals on the oxidation processes of cookie fats with sunflower oil can be influenced by several factors. Firstly, their composition includes dietary fibers that bind fat and diffusively inhibit the access of oxygen to its molecules. Secondly, the additives contain phenolic compounds and vitamin E, which are powerful natural antioxidants.

It is known that peroxide compounds break down to form secondary oxidation products (aldehydes, ketones, etc.), which contribute to the taste perception of bitterness in fatty products. An analysis of the organoleptic quality indicators of the investigated samples showed that after 35 days of storage, none of the products showed signs of rancidity (Table 4.10).

It is worth noting that after the storage period, the samples with the addition of CM and WM are close to the control in terms of organoleptic characteristics. In the sample made on a blend of margarine and oil, after 35 days of storage, the organoleptic characteristics deteriorate: visible fatty spots on the surface, crumbliness decreases, the color darkens, and a greasy taste is perceived.

Table 4.10 – **Changes in organoleptic indicators of cookie samples during storage**

<table>
<tr><th rowspan="2">Sample of cookies</th><th colspan="2">Storage duration, days</th></tr>
<tr><th>0</th><th>35</th></tr>
<tr><td rowspan="2">on margarine (control)</td><td colspan="2">Yellow color. The structure is crispy, crumbly</td></tr>
<tr><td>Taste and smell correspond to this type of product, without foreign tastes and odors</td><td>Taste and smell have weakened, but remain well pronounced, pleasant</td></tr>
<tr><td>on a mixture of margarine and oil</td><td>aste and smell correspond to this type of product, without foreign tastes and odors. Yellow color. The structure is crispy, crumbly</td><td>The color has darkened, taste sensations have weakened and diminished. The structure is somewhat moistened, crumbliness is worsened. The surface is oily with fatty spots</td></tr>
<tr><td>On a mixture of margarine and oil with CM</td><td rowspan="2">The taste and aroma correspond to this type of product, without any extraneous flavors or odors. The color is yellowish-brown. The texture is crisp and crumbly. It has a pleasant nutty flavor</td><td rowspan="2">The color is yellowish-brown. The texture is crisp and crumbly. The taste and aroma have weakened but remain well perceptible, pleasant, with a flavor reminiscent of the respective type of nut</td></tr>
<tr><td>On a mixture of margarine and oil with WM</td></tr>
</table>

According to the microbiological quality indicators, all examined samples of butter biscuits comply with the standards established for this type of product (Table 4.11).

Table 4.11 – **Changes in microbiological indicators of test samples during storage**

Indicator	MPC	Storage duration of cookie samples, days							
		On margarine		On margarine and oil mixture					
				Without additives		With CM		With WM	
		0	35	0	35	0	35	0	35
MAFAM, CFU/g, not more than	1×10^4	< 10							
Coliform bacteria (in 0.1g)	Not allowed	Not detected							
Pathogenic microorganisms, including Salmonella bacteria (in 25g)	Not allowed	Not detected							
Mold fungi, CFU/g	Not allowed	Not detected							

Therefore, it is noted that the use of nut meals (CM and WM) in the technology of butter biscuits made with a mixture of margarine and sunflower oil allows obtaining products with stable quality indicators during storage.

4.5. Comprehensive assessment of the quality of new products

To obtain a general characterization of the quality level of the developed types of shortbread-like butter biscuits, we conducted a comprehensive assessment using the qualimetry methods [251, 252].

The quality of the butter biscuits (P_0) is formed through organoleptic (PA), physicochemical characteristics (PB), food, energy value, and chemical composition (PC) (Fig. 4.8).

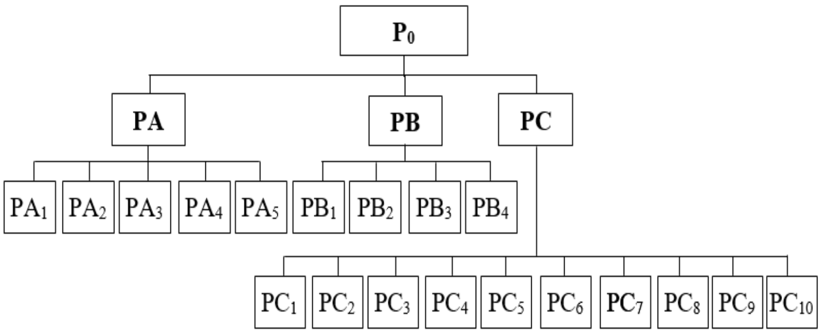

Fig. 4.9. "Property Tree" of shortbread-like butter biscuits:

Level 0: Comprehensive quality indicator; ***Level 1***: PA – organoleptic indicators, PB – physicochemical indicators, PC – chemical composition and energy value; ***Level 2***: PA_1 – shape; PA_2 – surface condition, PA_3 – color, PA_4 – taste and aroma, PA_5 – fracture appearance, PB_1 – moisture content, PB_2 – wetting capacity, PB_3 – alkalinity, PB_4 – strength, PC_1 – protein content, PC_2 – PUFA content, PC_3 – dietary fiber content, PC_4 – polyphenol content, PC_5 – vitamin E content, PC_6 – iron content, PC_7 – potassium content, PC_8 – calcium content, PC_9 – magnesium content, PC_{10} – energy value.

These specified groups of properties are further differentiated into respective individual quality indicators.

Absolute values of organoleptic indicators of the tested samples (group PA) were established using an expert method based on a 50-point system. The determination of physicochemical indicators (group PB) was conducted using instrumental methods, and the assessment of the chemical composition and energy value (group PC) was done through calculations. Absolute values of individual indicators were converted into dimensionless relative values (k_i) in relation to their baseline values according to formulas 4.1 (if an increase in the indicator value contributes to the improvement of product quality) and 4.2 (if an increase in the indicator value leads to a decrease in product quality).

$$k_i = P_i / P_i^{base} \tag{4.1}$$

$$k_i = P_i^{base} / P_i \tag{4.2}$$

where:

P_i – the absolute value of the i-th product quality indicator;

P_i^{base} – the baseline value of the indicator.

For the baseline values (P_i^{base}), the best indicators among the tested samples were chosen (excluding PC_4). For the PC_4 property, the daily human body requirement for polyphenolic substances was chosen as the baseline. The results of determining the group complex quality indicators are presented in Table 4.12.

The scale for evaluating complex quality indicators consists of five ranges: "very good" – 1.00....0.80; "good" – 0.80....0.63; "satisfactory" – 0.63....0.37; "poor" – 0.37....0.20; "very poor" – 0.20....0.00. It has been established that the samples of cookies with the addition of nut meals in all property groups are characterized by a "very good" rating.

Table 4.12 – **Group complex quality indicators of investigated cookie samples**

Quality Indicator	Weight Coef-ficient, m_i	P_i^{base}	Cookie								
			Without additives			With CM			With WM		
			P_i	k_i	$k_i \cdot m_i$	P_i	k_i	$k_i \cdot m_i$	P_i	k_i	$k_i \cdot m_i$
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Property group A											
Shape, points	0.15	50	49	0.98	0.15	47	0.94	0.14	46	0.92	0.14
Surface condition, points	0.10	50	49	0.98	0.10	46	0.92	0.09	46	0.92	0.09
Color, points	0.20	50	50	1.00	0.20	47	0.94	0.19	46	0.92	0.18
Taste and smell, points	0.34	50	47	0.94	0.32	49	0.98	0.33	49	0.98	0.33
Fracture appearance, points	0.21	50	48	0.96	0.20	46	0.92	0.19	46	0.92	0.19
Total quality index (K_{RA})*					**0.97**			**0.95**			**0.94**
Property group B											
Moisture content, %	0.29	4.95	4.2	0.85	0.25	4.7	0.95	0.28	4.95	1.00	0.29
Wetting capacity, %	0.31	208.2	160	0.77	0.24	208.2	1.00	0.31	202.2	0.97	0.30
Alkalinity, degrees	0.23	0.86	1.61	0.53	0.12	0.99	0.87	0.20	0.86	1.00	0.23
Strength, $\times 10^3$, Pa	0.17	320	320	1.00	0.17	360	0.89	0.15	350	0.91	0.16
Total quality index (K_{RB})					**0.78**			**0.94**			**0.98**

Continuation of Table 4.12

1	2	3	4	5	6	7	8	9	10	11	12
Property group C											
Protein content, %	0.2	12.68	7.4	0.58	0.12	12.68	1.00	0.20	11.5	0.91	0.18
PUFA content, %	0.2	10.49	3.77	0.36	0.07	9.65	0.92	0.18	10.49	1.00	0.20
Dietary fiber content, %	0.16	4.2	0.88	0.21	0.03	4.2	1.00	0.16	2.6	0.62	0.10
Polyphenol content, mg/100g	0.1	200	0.00	0.00	0.00	267.17	1.00	0.10	800.6	1.00	0.10
Vitamin E content, mg/100g	0.16	10.53	3.52	0.33	0.05	10.53	1.00	0.16	10.23	0.97	0.16
Iron content, mg/100g	0.04	3.03	0.66	0.22	0.01	1.31	0.43	0.02	3.03	1.00	0.04
Potassium content, mg/100g	0.04	310.31	87.68	0.28	0.01	310.31	1.00	0.04	233.64	0.75	0.03
Calcium content, mg/100g	0.04	66.97	20.39	0.30	0.01	19.87	0.30	0.01	66.97	1.00	0.04
Magnesium content, mg/100g	0.03	81.86	10.6	0.13	0.00	81.86	1.00	0.03	58.71	0.72	0.02
Energy value, kcal/100g	0.03	534.7	534.7	1.00	0.03	551.8	0.97	0.03	557.7	0.96	0.03
Total quality index (K_{RC})					**0.34**			**0.93**			**0.90**

* The group complex quality index

The new products slightly lag behind the control sample in organoleptic indicators but surpass it in physicochemical characteristics and chemical composition. In particular, the control sample, in the group of properties characterizing chemical composition and nutritional value, has a rating of 0.34, which is categorized as "poor," attributed to its low content of vitamin E, minerals, PUFA, dietary fiber, and the absence of polyphenolic compounds.

The comprehensive quality assessment was determined by taking into account the group comprehensive assessment (K_i) for organoleptic properties (K_{RA}), physicochemical indicators (K_{RB}), chemical composition, and energy value (K_{RC}), along with the respective weight coefficients (Table 4.13) using the formula (4.3).

$$K_i = \sum_{i=1}^{n} k_i \cdot m_i, \qquad (4.3)$$

Where: m_i – weight coefficient of the i-th indicator;

n – the number of quality indicators;

k_i – relative quality indicator.

Table 4.13 – **Quality assessment of investigated cookie samples**

Property Group	m_i	Cookie					
		Without additives		With CM		With WM	
		K_i	$K_i \cdot m_i$	K_i	$K_i \cdot m_i$	K_i	$K_i \cdot m_i$
PA	0.38	0.97	0.37	0.95	0.36	0.94	0.36
PB	0.27	0.78	0.21	0.95	0.26	0.98	0.26
PC	0.35	0.34	0.12	0.93	0.33	0.9	0.32
Total quality index			0.70		0.94		0.94

It is noted that the cookies with the addition of nut meal have the same comprehensive quality index, corresponding to the rating "excellent," and exceed the control sample by 25.5%. The control sample of cookies is rated as "good."

Therefore, the efficiency of using cedar and walnut meal in the technology of sand-vein butter biscuits made on a mixture of margarine and sunflower oil has been proven through the calculation of the comprehensive quality index.

4.6. Evaluating the attractiveness of a new technology for a manufacturer

To justify the feasibility of implementing technologies for the production of sand-vein butter biscuits with the addition of nut meal in practical activities, an expert survey method was used to assess the attractiveness of the developed products (cookies with CM, cookies with WM) for producers. The expert group consisted of 16 specialists in the field of organizing food production. The list of main characteristics for assessing the attractiveness of the new food product was formed based on the results of content analysis of scientific literature on the study of the effectiveness of innovative developments [255–257]. Taking into account the results of the conducted research, the assessment of the attractiveness of the new food product was carried out using a set of indicators reflecting market, commodity, sales, and production advantages of producing the new product for the manufacturer. For the quantitative measurement of the advantages of the developed product, a scoring method was used with the application of a specific rating scale: a high value of the indicator - 3 points, average - 2 points, low - 1 point. To make a generalized conclusion about the feasibility of implementing the developed technologies in the practice of economic activity, the attractiveness coefficient of the new product for the manufacturer was calculated using the formula:

$$K_p = \sum_{j=1}^{n} \sum_{i=1}^{m} P_{ij} / \sum_{i=1}^{m} P_{imax} \ , \qquad (4.4)$$

Where:

K_p – the attractiveness coefficient of the new product;

P_{ij} – the number of points assigned by expert j to indicator i;

P_{imax} – the maximum value of indicator i for the attractiveness of the new product;

n – the number of experts;

m – the number of indicators.

Criteria, indicators, and the rating scale for assessing the attractiveness of the new product are presented in Tables 4.14 and 4.15.

Table 4.14 – **Scale for assessing the level of attractiveness of food products for the manufacturer**

The values of the coefficient	Conclusions
$0 < K_p \leq 0{,}33$	low attractiveness of the new product for the manufacturer
$0{,}34 < K_p \leq 0{,}66$	slight attractiveness of the new product for the manufacturer
$0{,}67 < K_p \leq 1{,}0$	high attractiveness of the new product for the manufacturer

Table 4.15 – **Characteristics and evaluation scale of food production technologies based on the attractiveness criteria**

Criterion	Evaluation		
	High level (3 points)	Medium level (2 points)	Low level (1 point)
1	*2*	*3*	*4*
Market criteria			
Demand for the new product	The product meets a new need, significantly improved compared to the analog	The product is improved only in secondary characteristics, which, however, are essential for a wide range of consumers	The product does not differ from analogs and satisfies the same needs
Compe-titiveness of the product	There are no strong competitors. Low cost of production	Competitors have strong positions, and the cost of innovation is relatively low	Few equally strong competitors dominate the market. The cost of developing a product similar to competitors is too high
Market develop-ment prospects	Homogeneous nationwide market with significant development prospects, involving various layers of buyers. Large potential opportunities for export	The market is stable, with the potential for growth in individual regions due to expanding the circle of buyers. Limited opportunities for export	Few equally strong competitors dominate the market
Stability of market dynamics	With a high probability, it can be predicted that the demand for the product will be constant	The product will have sufficient demand for a long time, allowing the investment to pay off and generate profits	Uncertainty regarding the stability of demand for the product

Continuation of Table 4.15

1	2	3	4
Product criteria			
Product properties	The product has unique properties, significantly superior to competitive products, and is patented	The product has unique properties that significantly surpass those of competitive products, but the patent reliability is low. Properties of the product are difficult to copy	The production technology is not patented and can be easily copied by competitors
Price	The product is of equal or better quality than competitive products but is sold at lower prices	The product is offered at the same prices as competitors but has higher quality	The product has the same quality as competitive products but is offered at a higher price
Production criteria			
Raw materials	Traditional raw materials are used. There is an opportunity to continue purchasing them from main suppliers	Mostly existing raw materials are used, but there may be a need to purchase additional raw materials from both traditional and new suppliers.	Existing raw materials will be used insufficiently or are entirely unsuitable. Large purchases of raw materials are needed
Equip-ment	There is no need for additional equipment	There is a need for additional equipment	New equipment is required for the production of the new product
Personnel	The product provides favorable conditions for improving knowledge and skills of the staff	There is a need to improve the qualifications and increase the number of personnel	The experience of personnel may be partially used for the production of the new product

Continuation of Table 4.15

1	2	3	4
Sales criteria			
Sales cycle	The product has low dependence on economic fluctuations and cycles in the economy	The sale of the product has little dependence on economic fluctuations and cycles in the economy	The sale of the product significantly depends on economic fluctuations and cycles in the economy
Sea-sonality of sales	The sale of the product is not seasonal	The sale of the product is mainly seasonal	The sale of the product is seasonal

Compiled based on materials [256]

The results of the conducted research demonstrate the expediency of implementing into production the developed technology of sand-extracted butter biscuits with the addition of nutmeal. It has been established that the developed types of butter biscuits are characterized by a high content of proteins, polyunsaturated fatty acids, dietary fibers, polyphenols, vitamin E, and minerals (K, Cu, Mg, Mn, Fe), meeting consumer expectations regarding the properties of food products.

According to published data [258], there are approximately 30 specialized confectionery companies operating in the confectionery product market, producing a diversified range of sweets. In addition to large companies, there are about 600 small confectionery product manufacturers in Ukraine (including bakeries that mainly produce flour confectionery products).

Despite this, the Ukrainian confectionery product market is considered moderately concentrated. It is worth noting that cookies are among the confectionery products that are most in demand among the population. According to Nielsen company estimates, cookies are among the top three most demanded confectionery products on the consumer market. In the total sales volume of confectionery products in 2018, cookies accounted for 19.5% of the total sales [259].

Regarding the product characteristics of the new production, it should be noted that changes in the recipe of cookies result in higher cost and price indicators for the new product. However, the use of nut meal in the technology of sand-sponge cookies on a combined fat basis allows obtaining products with stable organoleptic, microbiological, and physico-chemical quality indicators during storage. This compensates for the higher production cost and ensures competitiveness. It is also noteworthy that the developed product has a high level of patent protection (patent No. 100817).

The developed product has certain advantages in terms of its production and marketing. Traditional raw materials are used for the production of cookies with nut meal, ensuring stability and reducing the risks of process technology violations. Additionally, the developed technologies can be implemented in existing production without changing the technical and equipment base, and without additional costs for staff training. The product is not sensitive to economic and seasonal cycles, providing for its production and sales throughout the year, which offers advantages compared to seasonal products. Nut meals inhibit the migration of fats from such cookies and slow down the rate of oxidative processes, providing additional advantages in terms of extending shelf life.

Taking into account the information presented above, experts have assessed the attractiveness of food production technologies based on the criteria of attractiveness of the new product (Table 4.16).

Table 4.16 – **Evaluation of the attractiveness of cookies with nut meal for the manufacturer**

Indicator	Evaluation, points		Attractiveness coefficient	Conclusion	Characteristic
	Max	Actual			
1	*2*	*3*	*4*	*5*	*6*
Market criteria					
Demand for new products	3	2.50	0.83	HA	The product stands out with high quality, leading to demand
Production competitiveness	3	2.50	0.83	HA	The product is competitive in terms of quality and price
Market development prospects	3	2.63	0.88	HA	The production volume and market capacity for confectionery are growing
Market development prospects	3	2.88	0.96	HA	Cookies are among the top three most demanded confectionery products in the consumer market
Total	12	10.50	0.88	HA	–
Average	3	2.63	0.88	HA	–
Product criteria					
Properties of the product	3	2.88	0.96	HA	Organoleptic, microbiological, and physico-chemical indicators meet regulatory values
Price	3	1.88	0.63	MA	The price of the new product corresponds to prices for analogous products
Total	6	4.75	0.79	HA	–
Average	3	2.38	0.79	HA	–

Continuation of Table 4.16

1	2	3	4	5	6
Production criteria					
Raw materials	3	2.56	0.85	HA	Traditional raw materials are used for the production of the product
Equipment	3	2.56	0.85	HA	There is no need for equipment changes
Personnel	3	2.88	0.96	HA	There is no need for personnel training
Total	9	8.00	0.89	HA	–
Average	3	2.67	0.89	HA	–
Sales criteria					
Sales cycle	3	2.63	0.88	HA	The product is not sensitive to economic cycles
Seasonality of sales	3	2.56	0.85	HA	The product does not belong to the group of seasonal products; it enjoys demand throughout the year
Total	6	5.19	0.86	HA	–
Average	3	2.59	0.86	HA	–
Overall	33	28.44	0.86	HA	–

Marks: LA – low attractiveness of new product for the manufacturer; MA – moderate attractiveness of new product for the manufacturer; HA – high attractiveness of new product for the manufacturer

According to calculations, the overall attractiveness coefficient for the product is 0.86 (with a maximum coefficient value of 1.0), indicating the high value of sand-sponge cookies on a combined fat basis with the addition of nut meal for the manufacturer. High values for market (0.88), product (0.79), production (0.89), and sales (0.86) advantages indicate significant prospects for the implementation of the developed technology in the practical activities of food industry enterprises.

Conclusions from Chapter 4

1. The optimization of the ratio of recipe components for sandy-sponge cake on a mixture of margarine and sunflower oil with the addition of nut meal has been conducted. As a result, it was determined that the dosage of PUFA should be 15.8% of the total mass of recipe components, sunflower oil – 32.2% of the margarine mass, and powdered sugar – 15.8% of the total mass of recipe components. For cookies with WM, the dosage of these components should be 15.3%, 34.1%, and 17.0%, respectively.

2. Two recipes for cookies with such additives and the technology of their production have been proposed, which differ from existing ones in that refined sunflower oil and walnut meal are additionally introduced at the emulsion formation stage. The introduction of walnut meal at this stage is justified by its high fat-holding and fat-emulsifying properties.

3. Cookies with a mixture of margarine and sunflower oil, supplemented with nut meal, are characterized by higher protein content, polyunsaturated fatty acids, dietary fiber, polyphenols, vitamin E, and minerals (K, Cu, Mg, Mn, Fe).

4. The use of CM and WM has an inhibitory effect on the degree of fat migration during the storage of cookies with a mixture of margarine and oil (74.1% and 78.8%, respectively) and on the course of oxidative processes (37.1% and 45.1%).

5. According to the comprehensive quality index, cookies with the addition of sunflower oil and nut meal exceed the control sample by 25.5%, demonstrating the social effectiveness of the new development.

6. The evaluation of the new product based on attractiveness characteristics for implementation in production proves its high level of efficiency. The overall attractiveness coefficient of cookies with nut meal for the manufacturer was 0.86, indicating significant prospects for implementing such technology in the food industry.

CONCLUSION

Analytical review of the literature and summarization of scientific and technical information on the researched topic allowed identifying the prospects of using cedar meal and walnut meal in the technologies of sandy-sponge cake with liquid oil.

Cedar meal and walnut meal are characterized by a similar qualitative chemical composition. Proteins in cedar meal and walnut meal have a better amino acid score than wheat flour proteins for threonine, valine, methionine, cysteine, tryptophan, and lysine. Cedar meal contains three times more protein substances of the albumin and globulin fractions and almost twice the prolamin fraction, while walnut meal proteins are mainly represented by glutenins. Cedar meal and walnut meal contain 7.05% and 12.18% of fats, respectively, with a high degree of unsaturation – cedar meal is rich in linolenic acid, and walnut meal is rich in linoleic acid. Nut meal compositions include dietary fibers, minerals, vitamins, organic acids, and phenolic compounds.

In terms of particle size, nut meals exhibit higher dispersity than wheat flour. Particles with a size up to 40 μm constitute 50% of cedar meal, 46% of walnut meal, and only 29% of wheat flour. Nut meals demonstrate a high ability to emulsify refined sunflower oil and retain it under increased temperature conditions, justifying the substitution of a portion of margarine with sunflower oil in the butter biscuits recipe. Compared to high-grade wheat flour, cedar meal and walnut meal have lower indices of proteolytic activity but higher activity of α-amylase. In terms of lipase and lipoxygenase activity, nut meals slightly surpass wheat flour.

Nut meals contribute to a reduction in the gluten yield of wheat flour, a decrease in its hydration capacity, and simultaneously have a strengthening effect, manifested in certain changes in the physical and structural-mechanical properties of the dough – reducing its stability and increasing the degree of dilution under the action of mechanical processing. Walnut meal has a greater impact on wheat gluten.

The addition of cedar meal and walnut meal in an amount of 15.0% of the total mass of recipe components for cookies contributes to the improvement of the stability of the emulsion and the structural-mechanical properties of sandy dough with the addition of liquid oils.

By using nut meals in sandy-sponge cake with a replacement of 30% of margarine with sunflower oil, the product meets the requirements of regulatory documentation based on physico-chemical (moisture, swelling, alkalinity, and strength) and organoleptic indicators. The optimization of the ratio of recipe components for such cookies determined that the dosage of cedar meal should be 15.8% of the total mass of recipe components, sunflower oil – 32.2% of the margarine mass, and powdered sugar – 15.8% of the total mass of recipe components. For cookies with walnut meal, the dosage of these components should be 15.3%, 34.1%, and 17.0%, respectively.

Based on the optimization results, two formulations of cookies with CM and WM and the technology of their production have been developed. It differs from existing ones in that, at the emulsion formation stage, additional refined sunflower oil and walnut meal are introduced. The developed types of cookies, compared to the traditional sample with margarine, are characterized by a higher protein content (1.8 and 1.6 times, respectively), significantly enriched with non-starch polysaccharides (4.7 and 2.9 times), polyunsaturated fatty acids (2.5 and 2.8 times), vitamin E (almost 3 times), and minerals (K, Cu, Mg, Mn, Fe). Importantly, the cookies are enriched with polyphenolic compounds, which are absent in the control sample.

The use of walnut meal in the technology of cookies with liquid oils allows obtaining products with stable organoleptic, microbiological, and physicochemical quality indicators during storage. Walnut meal inhibits the migration of fats from such cookies and slows down the rate of oxidative processes.

By the value of the comprehensive quality indicator, cookies with liquid oil and the addition of walnut meal exceed the control sample by 25.5%, demonstrating the social efficiency of the new development. The overall attractiveness coefficient of cookies with walnut meal for the manufacturer was 0.86, indicating significant prospects for the implementation of such technology in the practice of food industry enterprises.

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ANNEXES

Annex A.
Results of derivatographic studies of nut meal

Table A1

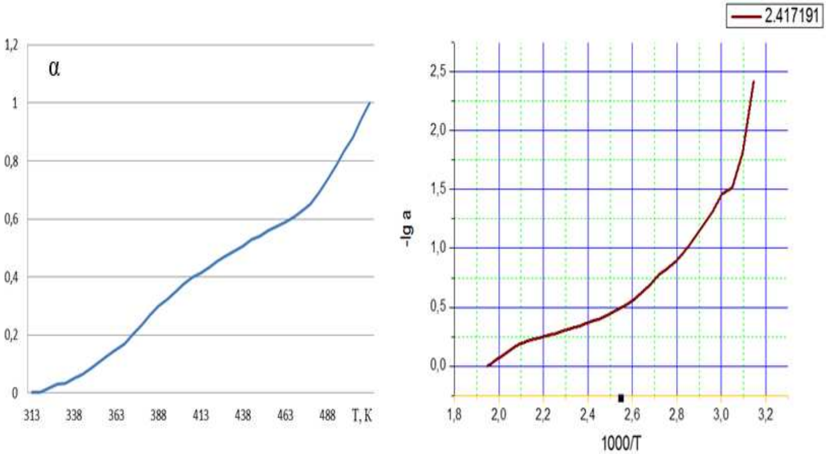
Results of thermal transformations of CM and WM samples

Meal	Δm_e, %	corres-ponds to fracture	Δm_e, %	corres-ponds to fracture	Δm_e, %	corres-ponds to fracture	Δm_e, %	corres-ponds to fracture
WM	20…155°C		155…225°C		225…340 °C		340 …412 °C	
	6,36	H_2O free	9,94	H_2O bound	31,28	decom-position	10	decom-position
	Δm_e (total) = 57,58%							
CM	20 to 170 °C		170 to 240 °C		240 to 300 °C		300 to 348 °C	
	7,73	H_2O free	6,88	H_2O bound	26,94	decom-position	12,6	decom-position
	Δm_e (total) = 54,1%							

Table A2

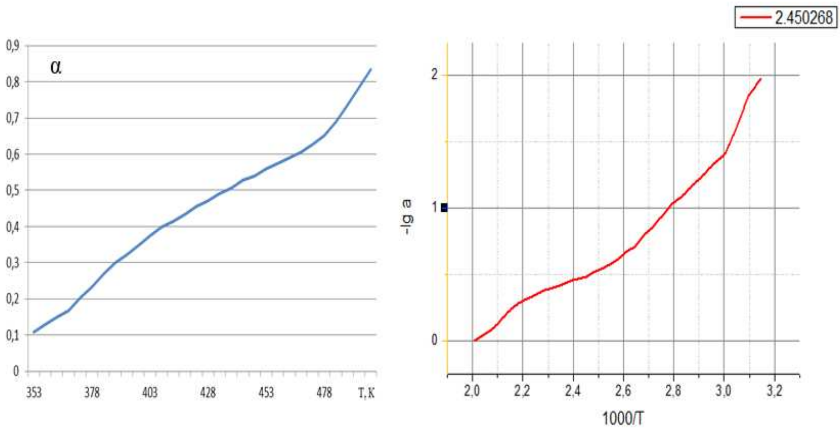
Peaks of derivatives for WM and CM

Effect	Maximum temperature	Effect	Maximum temperature
WM		CM	
1 endothermic peak	130	1 endothermic peak	125
2 endothermic peak	185	2 endothermic peak	202
1 exothermic peak	300	3 endothermic peak	241
2 exothermic peak	343	1 exothermic peak	310
3 exothermic peak	356	2 exothermic peak	343



a) b)

Fig. A1. Derivatogram processing results for CM: a) Dependence of the rate of mass change (α) on temperature (T); b) Dependence of – lgα –1000/T



a) b)

Fig. A2. Derivatogram processing results for WM: a) Dependence of the rate of mass change (α) on temperature (T); b) Dependence of – lgα –1000/T

Annex B
Alveograms of dough samples with the addition of nut meal

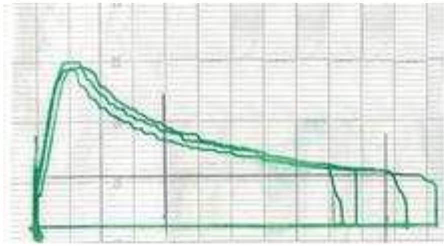
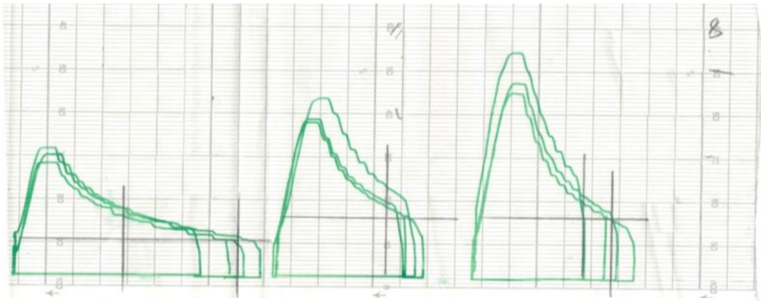
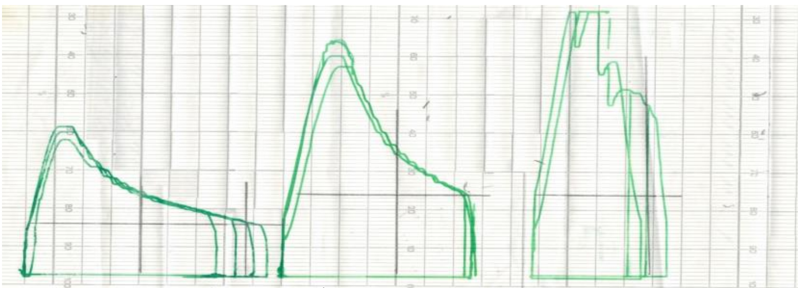


Fig. B1. Alveogram of the dough sample without additives (control)



a b c

Fig. B2. Alveograms of dough samples with the addition of CM: a) 5%; b) 10%; c) 15%



a b c

Fig. B3. Alveograms of dough samples with the addition of WM: a) 5%; b) 10%; c) 15%

Annex C
Farinograms of dough samples with added nut meal

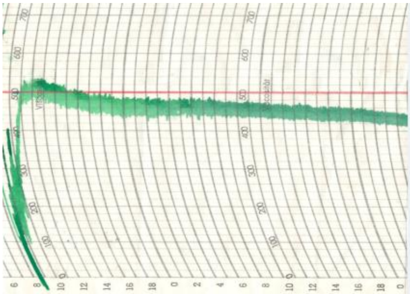


Fig. C1. Farinogram of dough sample without additives (control)

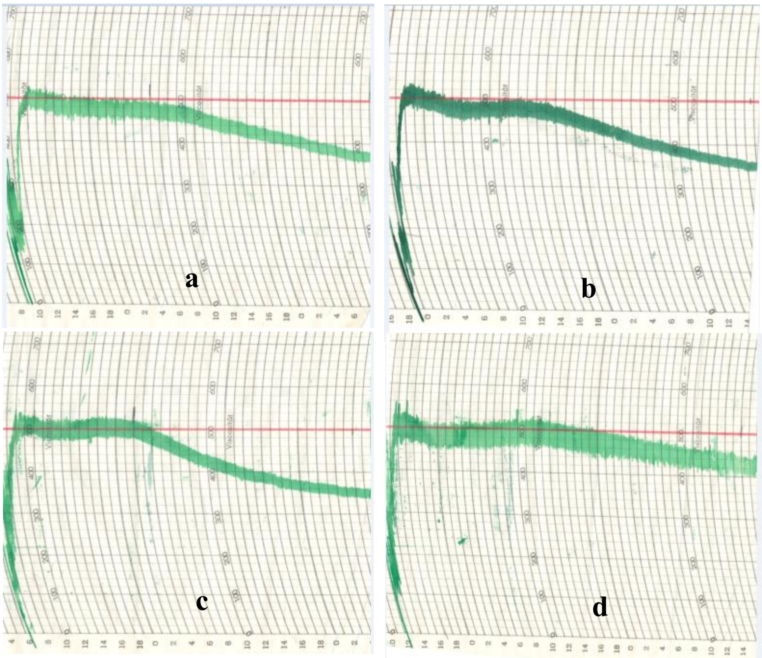


Fig. C2. Farinograms of dough samples with the addition of CM: a) 5%; b) 10%; c) 15%; d) 20%

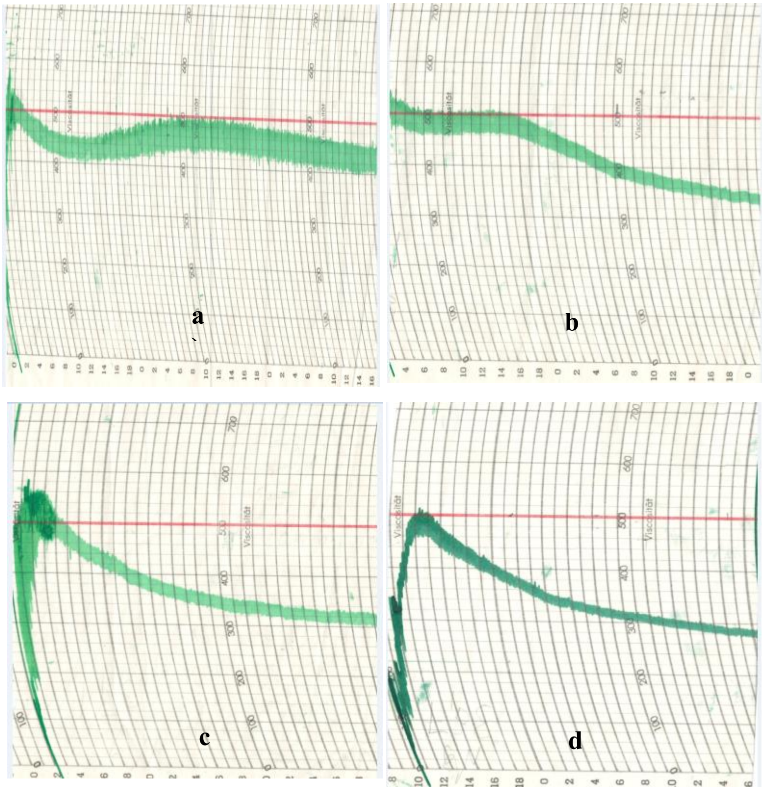


Fig. C3. Farinograms of dough samples with the addition of WM: a) 5%; b) 10%; c) 15%; d) 20%

Scientific publication

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