This paper reports the results of studying the effect of fat removal from wheat germ on its functional-technological properties, as well as its commercial potential, using the technology of butter biscuits as an example. The expediency of large-scale application of fat-free germ has been established for resolving two tasks at the same time: the introduction of the concept of lean manufacturing provided the germ utilization is scientifically justified, that is, creating value without losses. It has been noted that flour confectionery technology has prospects for the introduction of fat-free wheat germ.

It has been shown that although wheat germ has a unique chemical composition, it contains much fat, which contributes to the processes of oxidation and rancidity. It is the lack of a scientific base on the influence of the fat removal process on the functional-technological properties of fat-free wheat germ that is a deterrent for its application in the food industry.

The paper gives the results from studying the functional-technological properties of wheat germ from which fat was removed with freon-12.

The solubility of proteins of fat-free wheat germ depending on the pH has been investigated; it was determined that the conditions for pronounced solubility were created at pH 9.

It has been determined that NaCl at a concentration of 1...5 % does not affect the amount of dissolved protein.

The results from investigating the surface tension of wheat germ protein solutions and fat-free wheat germ depending on the medium pH are presented. The dependence of values of the surface activity of wheat germ protein solutions on pH has been established.

The dependence of the phase inversion point on the concentration of wheat germ and fat-free wheat germ has been investigated. It was determined that the emulsifying ability increases with an increase in the concentration of the suspension to 10 %.

A technological scheme for making butter biscuits with the use of fat-free wheat germ has been devised

Keywords: wheat germ, fat-free wheat germ, functional-technological properties, butter biscuits

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SUBSTANTIATING THE REMOVAL OF FAT IN THE TECHNOLOGY OF OBTAINING WHEAT GERM AND DEVISING TECHNOLOGY FOR MAKING COOKIES CONTAINING IT

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1. Introduction

Economic integration, the development of trade and tourist relations among the countries of the world is one of the main trends in the modern development of society, which leads to changes in the culture of food consumption. Given the current conditions for operating restaurant establishments, specialized shops, one of the main directions of development is to expand the range of products with properties understandable to all consumers, including the presence and content of basic nutrients. The commercial and social success of food and restaurant industry enterprises under these conditions depends not only on the taste attractiveness of the products sold but also on the indicators of consumer value of products, taking into consideration modern world food trends.

It is well known that nutrition is one of the most important factors that predetermine the state of health of the population. Scientifically based nutrition provides normal growth and development, it is a factor in the formation of harmony and efficiency, it promotes the prevention of diseases, determines active longevity. Food products have always performed the function of providing a person with the necessary macro-and micronutrients. The concept of "functional food products" implies the use of ingredients that have a positive effect on human health, can fill the deficit of relevant substances in the diet, contribute to the normalization of the functions of organs and systems of the human body [1]. Scientific substantiation and implementation of innovative solutions make it possible to provide consumers with high-quality food products that can prevent the formation of nutrient deficiency and become a source of necessary regulators for all functions of organs and systems of the human body.

One of the groups of foods consumed under any economic, social, or other conditions is confectionery. However, it should be noted that flour confectionery products belong to the most fat- and sugar-intensive foods [2]. It is the high content of carbohydrates and fats, the high energy value, and unbalanced content of nutrients, including dietary fiber, in the composition against the background of low biological value [3] that dictate the need to adjust the technological principles of flour confectionery. A relevant task for scientists is to optimize the chemical composition and increase the biological value of flour confectionery through the use of natural raw materials. It is almost impossible to solve the task of rapid adjustment of the nutrition structure by simply increasing production volumes and expanding the range of traditional food products. Therefore, the food industry is purposefully focused on innovative technologies, namely the search for raw materials, the latest technologies that make it possible to process agricultural raw materials without losing valuable biocomponents. Generally, ready-made trends in the development of the food industry are improving consumer properties, ensuring product safety; variation of shelf life, extending the range, and improving the food and biological value.

Consumer monitoring showed that chocolate bars (26.6 % in monetary units), cookies (19.5 %), and weight chocolates (17.3 %) are most popular among Ukrainians. These three categories generate more than 60 % of sales of the sweets market. The share of cookies in the group of flour confectionery reaches 42 % [4]. It should be understood that the general commodity name "Cookies" generalizes certain classification characteristics depending on the recipe composition and characteristics of the manufacturing process. An integral factor is the dependence of technology on market pricing, which most often affects the quality of products and their consumer value.

Important areas of increasing the nutritional and biological value of confectionery products are reducing the content of sugar and fat, and additional introduction into technological systems of proteins, vitamins, minerals, antioxidants, dietary fiber. This can be achieved both through the use of traditional raw ingredients and components of medicinal plants (licorice, echinacea, kelp, stevia, etc.) and by the addition of "pure" substances (proteins, amino acids, vitamins, etc.). One of the effective raw materials capable of performing the functions of an enricher in terms of the content of protein substances is wheat germ (WG), which has, at the same time, a high lipid content. Given the uniqueness of its chemical composition, WG is increasingly used in the food, pharmaceutical, cosmetology, microbiological, perfume industry, as well as medical industry. Data on the chemical composition of WG [5] (proteins – 23.15 g, fats – 9.72 g, carbohydrates – 38.6 g, dietary fiber –13.2 g), taking into consideration the raw material's potential, confirm the expediency of using WG in food enrichment technologies since it is inherently a natural carrier of important nutrients in a concentrated state. The flour that is not freed from germ is unstable during storage and deteriorates relatively quickly, so the technological scheme of modern processing enterprises involves the operation of its removal.

Given that under modern conditions the key requirement is the prolonged terms of sale of finished food products, it is the high content of time-labial lipids that is a deterrent to the widespread use of WG in the composition of flour confectionery. Ensuring stable technological properties of products in the process of manufacturing, storage, sale, and consumption is, at present, one of the preconditions for the commercial and social success of new products. Since the germ contains a lot of fat with a high content of unsaturated fatty acids, which are prone to self-oxidation (rancidity) under the influence of oxygen, it is this factor that would be a deterrent in the technologies of flour confectionery.

Given the full chemical composition of WG, this unique product can be considered an effective complex food enricher. In our view, its technological value could increase significantly if the technological process includes the mandatory stage of fat removal as a prerequisite for increasing resistance of both fat-free germ and products that contain it against oxidation. This circumstance is very important for products low in moisture content, such as cookies, since it is in such products that there is a pronounced threat of oxygenation of component lipids by oxygen from the air. Preliminary fat removal from WG for such products provides pronounced advantages, namely, a relative increase in the content of proteins in the product, as well as makes it possible to optimize storage conditions and prolong the sales time of such products. At the same time, information about the functional-technological properties of FWG is relevant and technologically important in order to substantiate the technology of confectionery products.

2. Literature review and problem statement

Flour production is a strategic industry both in the domestic market and in terms of export potential. According to data from [6], throughout 2017–2020, from 121.6 to 166.4 thousand tons of flour were produced each month in Ukraine.

Taking into consideration that the content of germ in wheat grains is about 3 % indicates that the production of WG is industrially expedient in terms of volume, while the raw material itself can be considered as a permanent component in terms of stability of provision with a pronounced marketing attractiveness for use in food products technologies. For use in confectionery flour products, it is obvious that the process of fat removal from wheat germ must be in place since, due to the high content of lipids in it, it is possible to predict the easy availability of oxygen and the oxidation of unsaturated fatty acids, which is the reason for the deterioration of its quality with loss of nutritional value.

The review of the literary sources in [6] reveals that the removal of fat from wheat germ by extracting vegetable oils from their composition is carried out by methods of pressing and extraction involving organic fat solvents.

The mechanical pressing of oil from the prepared oil material (pulp) at specialized auger presses is not effective for use in the technology of removing fat from WG since it does not provide for the complete removal of lipids.

Extraction is the process of transferring oil from oil-containing material to a solvent, carried out due to molecular and convective diffusion. The extraction process is based on the effective solubility of vegetable oils in non-polar organic solvents such as gasoline, hexane, dichloroethane, etc.

Solvents for the extraction of vegetable oils should ensure maximum yield, high-quality indicators of oil and meal, prevent the harmful effects of the solvent on the human body, and ensure the safety of working with them.

In the industry, the following solvents are used for the extraction of vegetable oils: aliphatic hydrocarbons obtained from oil, aromatic hydrocarbons, aliphatic alcohols, chlorine derivatives of aliphatic hydrocarbons. In addition, commonly used are gasoline, H-hexane, propane and butane, benzene, ethyl alcohol, acetone, freon-12. However, most often applied are gasoline and hexane, which have advantages and disadvantages [7].

Gasoline is the solvent that belongs to aliphatic hydrocarbons and is widely used for oil extraction. Their boiling point is 70...120 °C, their self-ignition temperature is 230...260 °C. The soluble capacity of gasoline for oils, fats, and waxes is 1:5. For the extraction of vegetable oils, extraction gasoline is used, which must meet the following requirements: the onset of boiling is not lower than 60 °C, the end-boiling point is not higher than 106 °C. The soluble capacity of gasoline increases with an increase in the number of light fractions in it.

In recent years, solvents such as pentane and hexane are widely used, which have a low boiling point – 40 and 70 °C. N-Hexane, similarly to gasoline, is a very volatile substance with a molecular weight of 86.2, a density of 663 kg/m^3 at 15.50 °C. N-hexane is mixed with fats and oils in all ratios, it has a boiling point of 66.7...69.3 °C, and does not contain aromatic hydrocarbons, unlike extraction gasoline.

Propane and butane are promising solvents, their peculiarity is that using them under an excess pressure of 0.4...1.2 MPa accelerates the extraction process by 2...3 times. The removal of propane and butane from oil and meal occurs at a temperature from 25 to 40 °C. After distilling propane and butane from oil and meal, there are no traces of solvent in them. Gasoline boils at a temperature of more than 85 °C; due to imperfect equipment, 0.1 % from the solvent distillation remains in the extraction oil.

Benzene is a liquid with a molecular weight of 78.12 and a boiling point of 80.2 °C. Benzene is poorly soluble in water (at a temperature of 20 °C – 0.08 g of benzene per 100 g of water). The soluble capacity, relative to oils and fats, is the same as that of gasoline, 1:5, but, due to high toxicity, it has limited use.

Ethyl alcohol is a liquid with a molecular weight of 46.07 and a boiling point of 78.3 °C, soluble in water. For oil extraction, alcohol is used in a 96 % concentration. Ethyl alcohol is used as a solvent in the extraction of soybean oil [7, 8].

Acetone is a liquid with a specific smell. Its molecular weight is 58.08; boiling point – 56 °C; self-ignition temperature – 500 °C. Acetone vapors in a mixture with air can self-ignite: the limit of the explosiveness of acetone vapors is on average 7.6 %; it is well soluble in water. The soluble capacity of acetone is the same as that of gasoline relative to oil and fats. Its peculiarity as a solvent is that it does not dissolve phosphatides. The above industrial solvents are not fully able to comply with the technological process, since elevated temperatures can impair the functional-technological properties of FWG proteins.

These disadvantages are eliminated when freons are used as extractants. Freon-12 is a promising solvent. This liquid boils at a temperature of 29.8 °C. A given solvent differs from other solvents in low fire resistance, it is non-toxic, is resistant to oxidizers and acids, volatile, chemically inert in relation to the extracted material. The rate of oil extraction from raw materials is higher by 1.2...1.5 times than that during gasoline extraction. The process of oil manufacturing occurs in the cold at the boiling point of freon. Freon-12 is distilled from oil and meal at a temperature from −5 to +5 °C. An analysis of the advantages and disadvantages of the above solvents has revealed the expediency of studying freon-12 in order to remove fat from WG. To enable fat removal, WG was predried to a moisture content of 3.5...4.5 % [7].

Most often, wheat germ is considered as a source of wheat germ oil (WGO) of useful oil, and the protein component is a by-product during its production [9]. For better WGO quality, methods such as ultra critical fluid fractionation, molecular distillation, as well as other innovative techniques, can be applied.

WGO consists of non-polar lipids, glycolipids, phospholipids, alcohols, complex esters, alkenes, aldehydes, tocopherols, n-alkanols, steroids, 4-methyl sterols, triterpenes, hydrocarbons, pigments, and volatile components.

The authors of work [7] consider the issue of obtaining wheat germ oil with hydrocarbon solvents of various types and their mixtures. They investigated the influence of the ratios of the three-component mixture of solvents (nefras, ethyl alcohol, isopropyl alcohol), as well as the ratios of wheat germ/solvent on oil yield. As a result, the optimal ratio of wheat germ:solvent of 5:100 was determined.

The oil extraction technique is used both in pure form and in combination with prepressing. To obtain oil from the germ, a prepressing scheme is used, that is, at the first stage, non-deep oil production presses are used. After prepressing, the meal is sent for extraction for the final production of oil. To increase the surface of contact between the solvent and raw material (meal), the latter is passed through a paired pressing roller with smooth rollers so that flakes are obtained [7, 8].

After removing oil from the wheat germ, fat-free wheat germ (FWG) is obtained, whose proteins have a balanced amino acid composition, high availability for enzymes of the gastrointestinal tract, which predetermines the expediency of their use as an effective protein enricher of food products.

It is obvious that the degree of influence on the protein component of wheat germ is determined not only by the parameters of technological processes but also by the choice of extractant. Under these conditions, the choice of freon-12 as an extractant is more appropriate since, in terms of the low temperatures of the lipid extraction range, it is a certain guarantee of reducing the degree of denaturation effect of protein.

Our review of the scientific literature reveals the high interest of industry scientists in the use of protein concentrate of wheat germ.

A study reported in [10] has confirmed the immunomodulatory activity of the new ECFSTA peptide from wheat germ globulin, which can also be used to substantiate and develop healthy foods.

Work [11] emphasized the anticancer activity of fermented wheat germ and its extracts.

Paper [5] proposes the use of wheat germ as physiological functional ingredients of raw materials in the production of confectionery products for patients with diabetes mellitus.

Study [12] provides data on the use of heat-processed wheat germ in the manufacture of crackers under the conditions of partial replacement of wheat flour.

It is interesting to use germ to adjust the rheological and enzymatical properties of bread dough [13].

Paper [1] considers the use of fat-flour and flour-fat compositions, the flour component of which is wheat germ flour, for functional flour confectionery using the example of sugar, short dough, and butter biscuits.

Underlying the technology is mixing in certain proportions of wheat germ flour of fresh yield with water-free fat, heated to 70...105 °C, or a mixture of fats and oils. At the same time with the heat treatment, the concentration of fat in the environment increases, which, along with the inactivation of BZP enzymes, helps prevent microbial contamination during storage. Such fatty compositions are also distinguished by the balance of the fatty acid composition. However, the cited work does not provide data on the impact of wheat germ on the time and storage conditions of finished products.

Papers [14, 15] proposed using a protein supplement from wheat germ in bread baking, yielding high-quality products with high nutritional and biological value for mass, therapeutic, and preventive nutrition in accordance with the requirements of nutrition science.

That is a positive result but the experience gained cannot be transferred to flour products with a long shelf life since bread is a product with a short selling period.

The above gives reason to believe that the issue of using WG and FWG in flour confectionery technologies is quite relevant and timely. However, it is obvious that the above data do not make it possible to establish the patterns of influence of the fat removal technique on the formation of the functional-technological properties of fat-free wheat germ. The conditions for modifying the functional properties of FWG and their objective assessment are not given, which could make it possible to substantiate the parameters of the technological processes of the formulation composition and their use in manufacturing. However, fat-removal technologies should ensure not only the maximum removal of it from the lipid component but also the preservation of its functional-technological properties such as moistening, solubilization, swelling, compatibility with the basic formulation components, in order to perform the functions of water and fat-retaining agents, emulsifiers. Under these restrictions, the fat-removal technology should be selected not only in terms of the effectiveness of lipid removal but also the minimal impact on proteins.

The would-be results of studying the effect of fat removal on the organoleptic, physicochemical, and functional-technological properties of WG could significantly expand its application in food technologies and, in particular, in confectionery products of improved nutritional value.

3. The aim and objectives of the study

The purpose of this study is to determine patterns in the formation of the functional-technological properties of wheat germ, which would make it possible to use it in the technologies of cookies with a long shelf life.

To accomplish the aim, the following tasks have been set:

– to determine the effect of removing fat from WG on the moisture-absorbing capacity of FWG;

– to determine the effect of the pH of the environment on the solubilization and solubility of proteins in WG and FWG;

– to establish the regularity of change in the surface tension of the technological system “WG-water” and “FWG-water” on the pH value;

– to determine the inversion points of the phases in the system “oil÷(WG-water)” and “oil÷(FWG-water)” on the mass fraction of WG and FWG;

– to devise a technological scheme for making cookies using FWG.

4. The study materials and methods

In the study, we used wheat germ from crop grains in 2019–2020.

The fat-free wheat germ was received at special installations under a recycling mode from wheat germ pre-dried to the solids content of 94.0–96.0 %. The content of lipids in wheat germ ranged depending on the season and origin from 8.6±0.2 % to 13.6±0.4 %.

The principle of the installation’s operation is based on a closed circuit in which the compressor is sequentially combined with a storage tank for liquid freon, an upper receiver, two parallel independent containers with fat-containing raw materials, a lower receiver for accumulating extracted oil. The lower receiver is equipped with heating to intensify the process of removing freon from the oil-freon mixture.

In the extraction cycle, one of the containers with fat-containing raw materials is consistently involved, while the other performs the function of a passive capacity in which the next batch filled with freon is stored for extraction, which significantly intensifies the fat removal process.

With the help of a compressor, the freon from the upper receiver fills the container with fat-containing raw materials by gravity, and, when impregnated through the germ of wheat, is enriched with the germ oil. After entering the lower receiver, the oil-freon mixture is heated under control to evaporate the freon and, through the upper hole of the receiver, with the help of a compressor, it is removed from the tank where the oil accumulates. Extraction lasts, depending on the fat capacity, for 18–36 hours. From oil and fat-free wheat germ, it is removed under a vacuum mode during controlled heating [16].

The protein content in WG and FWG was determined by the Lowry method in Miller’s modification.

To determine the solubility of proteins in the pH range of 1...12, we suspended the batch in distilled water, receiving a 1 % suspension. The suspension, at constant stirring, was kept in a thermostat at a temperature of 30 °C. After 15×60 s, the pH of the suspension was set, then 3 ml of samples were taken, the pH values were changed by unity, and the operation was repeated. The samples were centrifuged for 250 s^{-1} over 30×60 s; the over-deposit fluid was separated, in which we determined the protein content by absorption of the biuret complex at a wavelength of 540 nm at the Spekol ZV spectrometer (Germany). The gauge curve to determine the concentration of protein was built according to the whey albumin by the company Reanal, Hungary.

The surface tension was determined by the method of ring separation at a modified tensiometer Du Nui using a ring with a diameter of 19 mm, made of platinum wire with a diameter of 0.2 mm. The essence of the method is to measure the internal force necessary to tear the ring off the surface of the liquid. In advance, aqueous solutions were aged for (3´3,600) s in weighing bottles with tight lids to establish equilibrium.

The emulsifying ability of model systems was evaluated based on a phase inversion point.

10 ml of the suspension was placed in a glass with a capacity of 100 ml, fat was added with the help of a dividing funnel at a speed of 70...80 drops/min until the emulsion phases were inverted.

The type of emulsion was determined by a dilution method. The volume of the oil poured out of the funnel corresponded to the value of the phase inversion point.

We determined the water-absorbing capacity of protein isolates based on the Smyth method. 1 g of the sample was weighed in a 100 ml centrifuge test tube; we added 30 ml of distilled water, stirred for 60 s with a flat stirrer. We cleaned the stirrer by rinsing it with 5 ml of distilled water.

It was then centrifuged for 15 minutes at 9,000 *g*, poured over the sedimentary liquid; we put the centrifuge test tube in an inverted position on the filter paper to remove excess water. After 10 mins, the wet test tube was weighed.

The fat-absorbing capacity was determined by Method. 5 g of samples were weighed in the centrifuge test tube with a capacity of 100 ml; 25 ml of refined soybean oil was added. The suspension was stirred for 60 s with a flat stirrer. The mixture was aged (5×60) s, stirred again for 60 s and aged again (5×60) s. Then the centrifuge test tube was centrifuged at 1,500 *g*; we poured oil into the measuring cylinder and measured its volume. The centrifuge test tube was placed in an inverted position on the filter paper to remove excess oil; after 10 minutes, it was weighed.

The swelling coefficient (H) was determined by the weight method according to the ratio of change in the mass of the sample after immersion in the solvent for a certain period.

The objective value of color was determined using the MINOLTA CR-200 colorimeter, which makes it possible to determine the value of whiteness and brightness using selective scales. Measurements were carried out on a sample with a diameter of 2.5 cm. The value of whiteness was derived using the x, y, z system (Comision Internacional de Eclarage). The brightness of the samples was determined by the L^* value in the L, a, b system (Universal Chromatic Scale) as the average value based on the results from three measurements.

L^* defines the brightness and its magnitude based on a scale between 0 (black) and 100 (white). a^* specifies the level of shades: red if it has a sign (+) and green (–). b^* defines the level of shades: brown – (+) and blue – (–).

5. The results of studying the effect of fat removal on the functional-technological properties of wheat germ

Fat-free wheat germ is a product in the form of characteristic particles, odorless, with color from cream to light gray with content of residual lipids up to 1.7 %.

The texture is significantly different from wheat germ by the presence of characteristic looseness, low bulk mass, density, which is the result of the influence of the extractant and a change in the ratio of components towards the relative increase in the mass fraction of nitrogen-holding substances and fiber [17, 18].

When compressed, the mass is practically non-lump and is characterized by fragility typical of fat-free substances.

The mass can be mechanically ground with the formation of highly dispersed powders.

Technologically obvious is to determine the main functional-technological characteristics, which in the technology of confectionery flour products determine the conditions of dough formation and molding.

5. 1. Determining the effect of removing fat from wheat germ on the moisture-absorbing capacity of fat-free wheat germ

Data on the effect of removing fat from WG on moisture-absorbing capacity (swelling coefficient) makes it possible to predict the formulation for a confectionery product and patterns in the technological process.

Our comparison of the water-absorbing capacity of WG and FWG has shown that in the process of fat-removal, this indicator decreased by 39 % and amounted to 1.2 for FWG vs. 1.69 for WG. The loss of affinity with water significantly reduces the technological capabilities of fat-free WG and is a significant limiting factor in its use in traditional technologies. Moreover, FWG is characterized by high flotation and low wettability, which makes it difficult to form homogeneous systems with water. The wetting of FWG samples is very slow, which also does not make it possible to effectively implement its technological properties in most technologies. However, this is quite a positive factor to produce butter cookies since it is the minimal interaction of dry components with water that gives butter cookies crumbliness.

The results of laboratory tests indicate a decrease in the capacity of FWG to swell under conditions of elevated temperature. Thus, at an increase in the temperature from 14 to 75 °C, the lag in this indicator is 0.06 g for each degree of increase.

That means that at temperatures higher than 45 °C, FWG with water would form systems with a high rate of sedimentation, which does not allow it to be used as thickeners. At the specified temperatures, FWG does not form a cohesively bound mass, that is, it is characterized by a low ability to dough formation. This fact has been confirmed by establishing patterns in the hydrophilization of FWG by changing the pH value in the water dispersion of FWG.

5. 2. The impact of the pH of the medium on the solubilization and solubility of wheat germ proteins and fat-free wheat germ

The results of our experimental studies on establishing the effect of pH of the environment and table salt on the solubilization and solubility of proteins are shown in Fig. 1, 2. The regularities in the solubility of FWG proteins and in determining the intervals of transition of FWG from the state of suspension in water to the state of the solubilized and fully hydrated homogeneous system are illustrated in Fig. 1. One can see that at pH 8.0 for the proteins of WG and at pH 9.0 for the proteins of FWG, the conditions of pronounced solubility are created, which improve with the growth of pH.

Based on the analysis of these curves, one can see that in the pH zone from 3.5 to 7.5, proteins are characterized by a low affinity with water, so, in general, both WG and FWG within this pH interval form sedimentation-unstable systems.

Fig. 2 shows the protein solubility curves depending on pH at a table salt concentration of 1...5 %. Based on these curves, one can see that at the specified concentrations, table salt does not significantly affect the amount of dissolved protein in the region of pH 2...11.

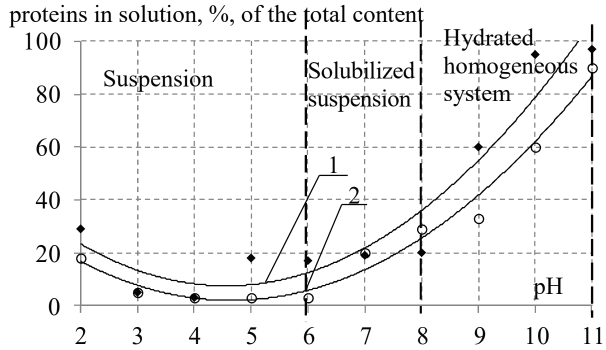

Fig. 1. The medium's pH dependence:
1 – wheat germ proteins solubility, $y=9,303x-24,17\ R^2=0,6429$;
2 – fat free wheat germ, $y=7,7455x-23,945\ R^2=0,6656$

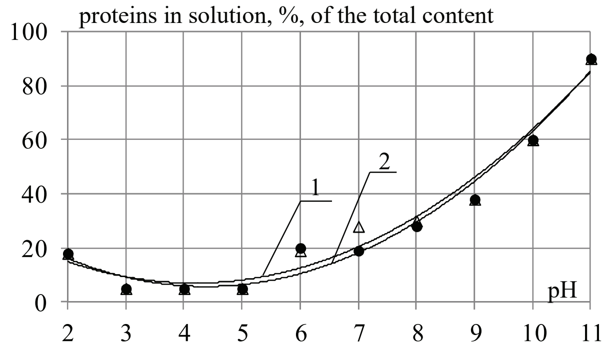

Fig. 2. The pH dependence at NaCl concentration:
1 – the solubility of wheat germ proteins, $y=7.6727x-21.073R^2$, NaCl=1.0 %; 2 – fat-free wheat germ, $y=7.7697x-20.703R^2$, NaCl=5.0 %

5. 3. The dependence of the surface tension of the technological system "wheat germ-water" and "fat-free wheat germ-water" on pH value

The surface activity of WG and FWG was determined on the basis of the surface tension of aqueous solutions of the examined objects at different pH values (Fig. 3).

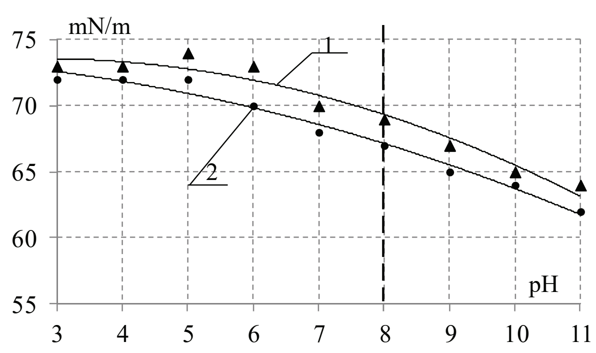

Fig. 3. Dependence of the surface tension (mN/m²) of the system "wheat germ–water" on the medium's pH:
1 – wheat germ, $y=-1.3x+78.878R^2$; 2 – fat-free wheat germ, $y=-1.35x+77.45R^2$

One can see that at acidic pH values they are characterized by low surface activity and do not change the surface tension, which is explained by the low solubility of proteins in this zone. At pH values close to neutral and slightly alkaline, the aqueous solutions of WG show greater surface activity than FWG. However, due to the low concentration of proteins in the solution, both objects at pH 8.0 reduce the surface tension from only 72.2 to 67.0 mN/m² for WG and to 69.0 mN/m² for FWG.

From these data, it is clear that when using these products as surfactants, it is necessary to adjust the pH in the alkaline direction.

5. 4. Determining the phase inversion point of the system "wheat germчwater" and "oilчfat-free wheat germ– water"

Fig. 4 summarizes data on the dependence of the phase inversion point of "oil–water" on the mass fraction of FWG and WG in the system "oil–wheat germ–water" and "oil–fat-free wheat germ–water".

We determined values of the phase inversion point based on a change in the mass fraction of germ from 1.0 to 12.0 %, characterized by different emulsifying capacities. However, for both samples, there is a monotonous increase in the emulsifying capacity in the system with an increase in the mass fraction of germ (Fig. 4).

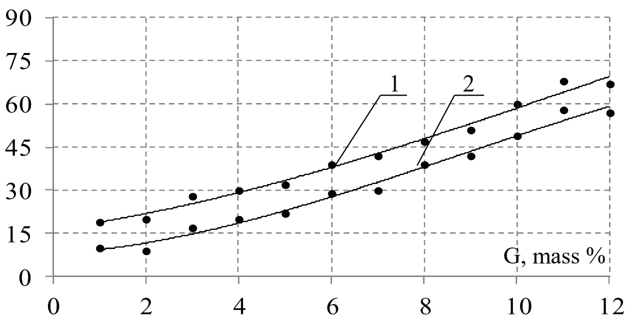

Fig. 4. The dependence of a phase inversion point on mass fraction, %: 1 — wheat germ, $y=4.6748x+11.53R^2$; 2 — fat-free wheat germ, $y=4.6993x+1.2879R^2$

The maximum values of the phase inversion point are accepted by WG and FWG, which, at a concentration of 10...12 %, were 67.2 and 59.0 volumetric units, respectively.

It has been determined that the fat-retaining capacity of FWG, in comparison with WG, increases by 10...12 %. This is likely explained by the fact that the FWG suspension has a greater affinity with fats.

One of the important technological indicators of WG and FWG is color, which was evaluated by the indicators of whiteness and color saturation.

Based on our analysis, it is clear that, given such technological factors, the color of FWG is characterized by sufficient stability. Fat-removal practically does not change the shade of the samples while their saturation increases.

5. 5. Devising a technological scheme for making cookies using fat-free wheat germ

Based on the data collected, we have substantiated the technological scheme for making shortbread cookies using FWG (Fig. 5). The technological scheme includes 4 basic interconnected subsystems; the result of their implementation is the obtained semi-finished products and finished products.

The manufacturing process of making butter biscuits using FWG involves the introduction of a series of technological flows – subsystems. Loose components are sieved, FWG is dispersed in oil, after which the dough is kneaded, it is molded, baked, and cooled.

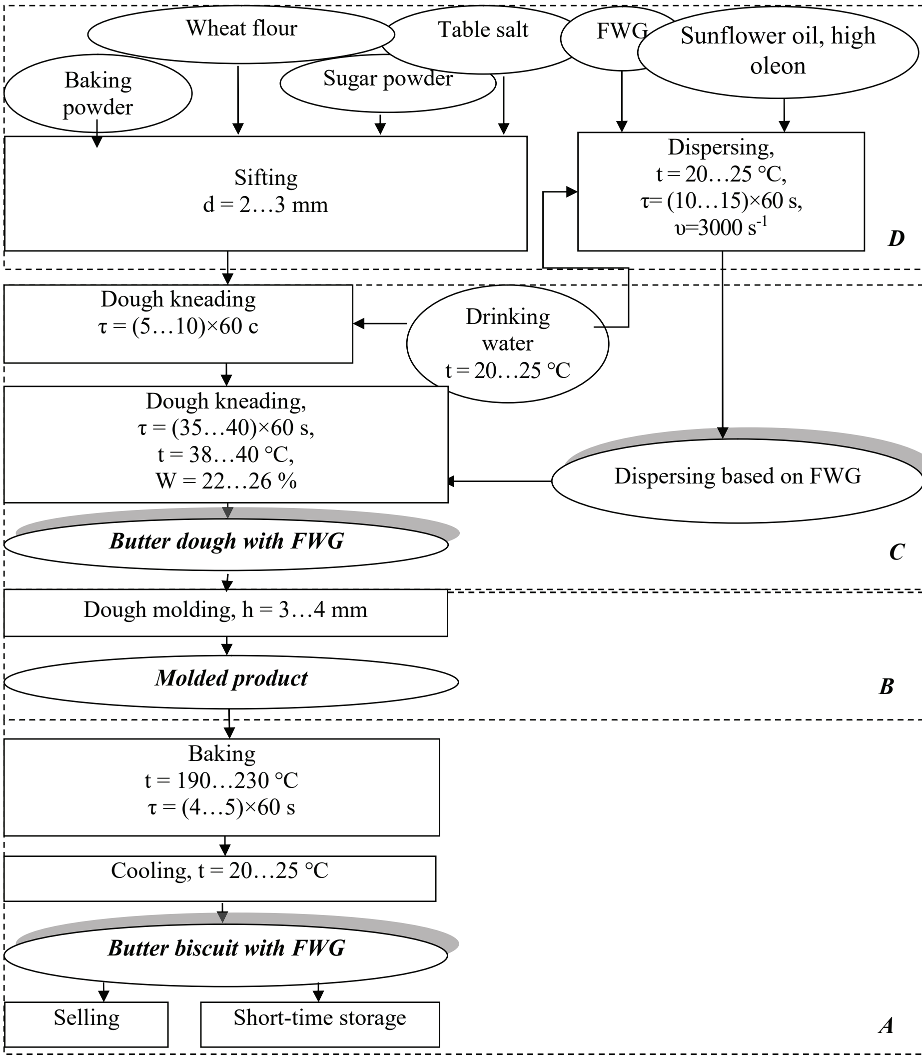

Fig. 5. Technological scheme for making butter biscuits using fat-free wheat germ

curve 1 against curve 2), the patterns of phase inversion (Fig. 4, curve 1 vs. curve 2); however, under these conditions, one observes in slightly alkaline zones both a drop in the surface tension (Fig. 3) and the growth of the phase stability of the emulsion. That additionally confirms the expediency of using FWG precisely in the technologies of flour products made from shortbread dough whose pH reaches the value of 8.5.

Our results suggest that the fat removal process impairs the solubility of proteins in the most favorable pH zone of 4.0...6.5 of organoleptic indicators, which is likely due to the denaturing effect of fat removal. Therefore, the use of FWG in the composition of products with an acidic pH value, including yeast dough, is not advisable from the point of view of both dough formation and the implementation of the functional-technological properties of FWG (Fig. 1). Quite opposite, since the pH of shortbread dough is weakly alkaline, an increase in the capacity of FWG proteins to swell (Fig. 1, 2) improves the retention of moisture in the middle of the product, restraining its drying in the process of storage, and, as a result, blocking the manifestation of the secondary process – oiling, which impairs its quality.

6. Discussion of results of studying the effect of fat removal on the functional-technological properties of wheat germ

Our study findings represent a series of systemic results for dough making when using fat-free wheat germ not only as a component enriched with proteins and dietary fibers but also related to the implementation of its functional-technological properties. To be introduced is the proposed technology for making cookies from shortbread dough, which are characterized by a long shelf-life period, a crumbly structure, high fat content; which contain mainly saturated fatty acids, as well as carbohydrates – starch, sugar.

It can be predicted that a decrease in the proportion of lipids, high in polyunsaturated fatty acids, as part of the fat-free wheat germ by 5–8 times to a content of 1.7 % is the key to increasing the stability of the fatty phase of cookies against oxidation in the process of its storing and to their prolonged shelf life, which was part of the purpose and objectives of the current study.

The use of freon-12 as an extracting agent, despite the low extraction temperatures [7, 8], is the reason for the denatured effect of wheat germ proteins, which is indirectly confirmed by the result of emulsifying capacity (Fig. 3,

Taking into consideration the data on the fractional composition of proteins in WG and FWG, protein solubility can also be adjusted by using salts and alcohols. However, it is clear that the nutritional concentrations of table salt in foods are very low (typically, about 1...2 %), and the use of alcohols in food technology is physiologically impractical [14].

When determining the solubility of FWG proteins depending on the pH at a NaCl concentration of 1 % and 5 %, the impossibility of obtaining a cohesively connected technological system with FWG has been confirmed. Therefore, from a technological point of view, the dough formation process is problematic.

The results of our study into the surface tension of protein solutions of WG and FWG on the medium's pH have confirmed that when using these ingredients as surfactants, it is necessary to adjust the pH of the system in the alkaline direction.

Even though a certain reduction in the emulsifying capacity of FWG has been established, which is explained by a decrease in solubility with the loss of affinity with water as a result of the action of freon-12, the FWG fat-retaining capacity increases by 10...12 % compared to WG. Hence, it follows that the FWG suspension has a more tangible affinity with fats, and, therefore, in cookies where fats are in a dispersed state, the FWG supplement would contribute to the stability of the heterogeneous system against stratification, which is very important for maintaining the stability of organoleptic indicators throughout the entire selling period.

At the same time, the finely-dispersed state of FWG in water and the established values of phase inversion points do not make it possible to recommend FWG as an effective emulsifier for direct emulsions, such as sauces.

Being aware of the need to realize the functional-technological properties, it is unquestionable that FWG might be used as an enricher with proteins with balanced amino acids, fats, carbohydrates.

Since the feature of technology for making butter shortbread cookies is a high fat content (about 26 %), sugar (18 %), while their moisture content should not exceed 20 %, FWG can act under such conditions as an additional baking powder agent. Taking into account that the technology involves flour with an average gluten content of 28...36 %, it is proposed to replace 20 % of starch in the cookie formulation with FWG.

The formulation of shortbread cookies implies the preparation of dispersion based on FWG and refined deodorized oil, and subsequent addition of other raw materials according to the formulation, which should ensure making finished products with traditional organoleptic indicators, high protein content, and low content of saturated fatty acids.

It has been experimentally determined that at a mass fraction of WGB of 10–20 % by weight, shortbread dough has high enough technological properties, is well molded, while the finished products have a suitable structure and crumbliness corresponding to this type of cookies.

The advantage of a given technology is the possibility of its implementation at traditional production lines.

Thus, the degree of using FWG aimed at achieving the desired characteristics of the resulting product in food systems is determined by the following factors:

– its functional-technological potential and the ability to implement it under specific technological conditions. Given this, the use of FWG in the composition of shortbread cookies is advisable;

– the mass fraction of FWG in a heterogeneous food system;

– the presence and parametric characteristics of the solvent as a formulation component;

– the pH value of the food system, which makes it possible to strengthen or reduce the affinity of products with solvents and change their surface activity;

– the coloration of the food system in terms of its match with the color of WGB and the possibility of FWG to form a formulation mixture of the required color in a food system;

– the colloidal, physical condition, and texture of the food system since FWG can be functionally active components in traditional food technologies only under certain conditions.

7. Conclusions

1. It has been shown that flour production in Ukraine is a strategic industry for both the domestic market and export potential and is characterized by large volumes of output. The expediency of removing fat from wheat germ and its use in food products has been substantiated. The concept of lean manufacturing was implemented on the basis of the scientific justification of using WG, that is, the creation of value without loss, by enriching the shortbread dough with FWG. We have determined the regularities of formation of the functional-technological properties of FWG, its solubility capacity in the pH interval of 1...12, and in the presence of 1–5 % of NaCl, the ability to change the surface tension of the system "water–WG (FWG)" depending on pH, as well as the emulsifying, water- and fat-absorbing capacities when removing fat from WG with the extractant freon-12.

The effect of removing fat from WG on the moisture-absorbing ability of FWG has been established. It was found that in the process of fat removal, the indicator of water-absorbing capacity decreased by 39 %, and, at temperatures higher than 45 °C, FWG with water form systems with a high rate of sedimentation, which does not allow it to be used as thickeners.

2. It has been confirmed that in the pH zone from 3.5 to 7.5 proteins are characterized by a low affinity with the water in WG, and, within this pH interval, FWG forms sedimentation unstable systems.

The growth of the surface activity and stabilization of heterogeneous food systems, including emulsions in the pH interval of more than 8.0, has been proven.

3. We have established the regularity of changes in the surface tension of the technological system "WG-water" and "FWG-water" depending on the value of pH. The aqueous solutions of WG show greater surface activity than FWG but, due to the low concentration of proteins in the solution, both objects at pH 8.0 reduce the surface tension only from 72.2 to 67.0 mN/m^2 for WG and up to 69.0 mN/m^2 for FWG.

4. The emulsifying properties of the system "oil÷(WG-water)" and "oil÷(FWG-water)" have been established. The maximum values of the phase inversion point are accepted by WG and FWG, at their mass fraction of 10...12 % they equaled 67.2 and 59.0. volumetric units, respectively.

5. The expediency of using FWG in the technologies of flour products from shortbread dough with the replacement of 20 % of potato starch in their formulation with FWG has been substantiated.

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