UDC 637.514:664.765
DOI 10.12737/1439

# EFFECT OF WHEAT GERM ON THE FUNCTIONAL PROPERTIES AND OXIDATION STABILITY OF GROUND MEAT SYSTEMS

**G. V. Gurinovich and I. S. Patrakova**

Kemerovo Institute of Food Science and Technology,
bul'v. Stroitelei 47, Kemerovo, 650056 Russia
phone:/Fax: +7 (3842) 39-68-57, e-mail: meat@kemtipp.ru

(Received January 11, 2013; Accepted in revised form February 26, 2013)

**Abstract:** The results of a study of the chemical composition and functional properties of the plant raw material in the form of wheat germ flakes (WGFs) with a view to combining it with a meat feedstock are represented. WGFs subjected to preliminary heat treatment in various modes (toasted) are studied. It is found that water-soluble and salt-soluble proteins of WGFs exhibit high solubility, which achieves maximum values of 45 ± 2% at a pH of 7.0–8.0 and a sodium chloride concentration of 2.0%. The functional properties of WGFs and dependences of the functional and technological properties of combined ground meat systems prepared of meat feedstocks of different types and nature of autolysis are determined. A preliminary heat treatment of WGFs does not decrease their functional properties, which are particularly shown in feedstock with anomalies in the development of autolysis, and contributes to a decrease in the oxidative transformation of lipids. In combined ground meat systems, toasted WGFs should be used in conjunction with 0.3% of a Delikaroma smoking flavor; this inhibits the oxidation of the lipid fraction of both raw and heat-treated ground meat systems.

**Key words:** meat, wheat germ, lipid fraction, toasting, oxidation inhibition

## INTRODUCTION

Meat products are traditional gastronomically valuable foods that have a long history of consumption. This is the main source of proteins with a high nutritional value, which have a significant effect on the protein metabolism of the human body. According to the modern concepts of nutritional science, the fraction of proteins should be 10–15% of dietary calories and animal proteins should be 50–60% of daily protein requirements. According to the data of the Institute of Nutrition of the Russian Academy of Medical Sciences (RAMS), the recommended intake of meat products depending on the age group of the population is 143 g/day (18–29 and 30–44 years old), 124 g/day (45–59 years old), and 85 g/day for people aged 60 years and over.

Analysis of the actual diet of Russians in recent years has revealed a number of positive tendencies in changing its structure and qualitative composition. The per capita consumption of biologically valuable foods, such as meat and meat products, milk and dairy products, eggs, and fish, has significantly increased, although it is still below the standard. A consequence of this is the lack of an animal protein (33%) at a total protein deficiency in human nutrition (at a level of 26%). These data provide a significant ground for the development of scientifically based ways of correcting the diet of the population. However, it should be remembered that an increase in the consumption of animal food is associated with an increased consumption of animal fats, which contain high amounts of saturated fatty acids.

Therefore, the modern concept of formulation of meat products involves not only an expansion of the product range and an increase in the volume of their production, but also the solution of a number of important problems, among which a particular position is held by the development of a technology for products meant for improving the nation's health and furthering the safety of products.

Scientists and experts in the implementation of this direction should pay particular attention to plant raw materials because the possibilities and prospects for the use of these materials are extremely broad. Cultivated and wild plant raw materials may be used as a basic ingredient or flavoring and aromatic components in the manufacture of general-purpose products, custom-designed food stuff, dietary supplements, and supplements exhibiting antioxidant and antimicrobial activity. Plant raw materials can be used to solve the problem of reducing the calorie intake with the compensation for the reduction of fat intake by carbohydrates, including complex carbohydrates, and replacing saturated fats with polyunsaturated fatty acids of plant raw materials.

Plant raw materials with a high content of proteins are of great importance in the meat product technology; the significance of proteins is determined not only by their nutritional value, but also by the involvement in the formation of the basic functional and technological characteristics of the feedstock and, consequently, the consumer properties of the products.

Analysis of scientific and engineering information shows an expansion of research into various types of plant raw materials as an alternative to traditionally used soybeans. Fairly well-known promising plants for producing flour and isolated and concentrated forms of proteins are lentils, chickpeas, peas, beans [1–4]. By-products of grain processing, in particular, wheat and rice bran, have a high technological potential [5, 6]. A high-protein feedstock for producing isolates and concentrates are nuts, such as peanuts, which contain 21% to 36% protein [7, 8], almonds containing about 33% protein [9, 10], and walnut [11]. Along with nuts, the researchers study seeds, extraction cakes, and press cakes of other oil-bearing crops, such as rape and flax; the protein content in press cakes of the last-mentioned plants is up to 54% [12, 13]. It should be noted that there is a keen interest in some plant species, in particular amaranth, a commercial use of which is possible in the near future [14]. These data suggest that the use of plant raw materials in food technology have broad possibilities; the combining of these materials with an animal feedstock for manufacturing products with a complex feedstock composition is a common practice in the world.

Wheat germ is of obvious interest in terms of nutritional value and the possibility of using it in the meat product technology. Despite small sizes of the germ (2.0–3.0% with respect to the mass of the grain), it is the most important part of the grain because it contains the primary organs of development of the plant, and this is responsible for its unique chemical composition. Wheat germ contains a large number of biologically active components; its protein is close to the physiologically active proteins of animal tissues and more fully-featured and balanced with respect to amino acid composition than the grain protein in general. This is attributed to the fact that gluten proteins, which are classified as reserve proteins, are mostly contained in whole grains, while biologically active proteins are dominant in the germ [15–18].

Wheat germ remains insufficiently demanded in the meat product technology because of scarce data on its technological capabilities and the pattern of interaction with components of the feedstock to be enriched in it.

A study of the fractional composition of the protein complex of wheat germ will make it possible to determine its affinity to muscle salt- and water-soluble proteins that are involved in the formation of stable meat systems and find the fraction of gluten proteins that can form a complex that stabilizes the product structure directly in meat systems.

Of great importance from the standpoint of safety and nutritional value of food products is the stability of their lipid component. According to the best available data, wheat germ contains phenolic components exhibiting antioxidant activity, including ubiquinone coenzymes and vitamins E [19]; at the same time, it contains prooxidant factors against the background of a high content of polyunsaturated fatty acids [20, 21]. It should be taken into account that the oxidation of lipids in the composition of meat products takes place under special conditions, which are primarily associated with the presence of heme pigments. Research into the redox potential of heme components has proved that coordinated iron of heme pigments is ideally suited for the role of an oxidation catalyst for fatty acids owing to the presence of unpaired electrons in their structure. Heme pigments are oxidized by hydroperoxides; this process is accompanied by a change in the valence of iron from $Fe^{2+}$ to $Fe^{3+}$; the resulting free radicals are involved in a variety of oxidation chain branching reactions [22].

Thermal action methods are efficient for the stabilization of wheat germ lipids; according to the best available data, these methods do not cause a significant change in the fatty acid profile and a decrease in the activity of phenolic antioxidants [23]. In addition, it is possible to improve their hygienic quality, particularly owing to a decrease in the activity of anti-nutritional factors, such as trypsin inhibitors [24, 25] and microbial contamination. Therefore, in this study, along with native wheat germ flakes (WGFs), previously toasted WGFs were analyzed. Heat pretreatment is also aimed at imparting improved organoleptic properties, particularly flavor and smell, to the germ. At the same time, heat pretreatment can also result in a change in the functional properties of wheat germ owing to a change in the protein and carbohydrate components and initiate the oxidation of labile lipids under complicated conditions of meat systems.

The aim of this study was to examine the chemical composition and functional and technological properties of wheat germ depending on the pretreatment method and its effect on the technological properties of ground meat systems prepared of feedstocks of different types and nature of autolysis and the stability of the lipid fraction of the systems in order to substantiate its use in the cooked sausage technology.

## RESEARCH OBJECTS AND METHODS

The object of study is edible wheat germ isolated during grain milling; it has the form of flat dry golden yellow petals, which are easily destroyed under mechanical action; it contains crushed shells, which do not change the color, and has a characteristic odor (Mel'korm flour mill, Kemerovo, Russia). The exterior features are responsible for the brand name of this raw material: WGFs.

The following samples were studied: WGFs unexposed to a pretreatment (native) $WGFs_{nat}$; WGFs subjected to conductive heating in two modes: 70°C with duration of exposure of 30 min ($WGFs_{70°C, 30}$) and 140°C with duration of exposure of 15 min ($WGFs_{140°C, 15}$); and WGFs subjected to dielectric heating at a frequency of 2450 MHz for 1.5 min ($WGFs_{microwave}$). The treatment was conducted in a thin layer with a thickness of no more than 1 cm. The treated WGFs were cooled at room temperature.

Taking into account a high specific weight of feedstocks with anomalies in the development of the autolysis, the following types of ground meat systems were used to study pH and water-binding capacity

(WBC): ground meat with normal autolysis (NOR beef, NOR pork, $pH_{24}$ of less than 6.2), exudative meat (PSE pork, $pH_{24}$ of 5.3), feedstock of a transient quality (PSE–NOR pork, $pH_{24}$ of 5.3–5.5), and dark, firm, and dry meat (DFD beef, $pH_{24}$ of more than 6.4). Wheat germ was introduced into the system in a hydrated form in a ratio with water of 1 : 2; the duration of hydration was 10 min; the temperature of water for hydration was 16–18°C, the level of introduction of hydrated WGFs was 5–20%.

In studying the stability of ground meat systems during heat treatment, ground meat models based on a feedstock with normal autolysis were used: refrigerated semifat pork or a mixture of semifat pork and first-grade trimmed beef taken in equal proportions. The meat feedstock was ground and admixed with 2.0% of sodium chloride; the mixture was stirred until a uniform distribution of the salt and kept in the salted state for 24 h. In each of the systems, 5.0, 10, and 15.0% of meat was replaced with WGFs hydrated during homogenization of the feedstock; the amount of process water was 20.0% with respect to the weight of the meat feedstock. The ground mea systems were placed in metal weighing bottles with tight-fitting lids and heated in water at a temperature of 85 ± 2°C; the temperature was controlled in an automatic mode with a chromel–copel thermocouple. The record of the thermocouple suggests that all the test samples were heated at an equal rate during a heat-treatment cycle of 15 min. Immediately after the treatment, the samples were cooled in an ice–water mixture and then recooled in the air in a cooling chamber at 6 ± 2°C.

To study the stability of the lipid fraction, a ground meat system based on semifat pork with the addition of 10% of toasted and native WGFs was used. Biotone Fos K-144 nutritional supplements (Budenheim, Germany), sodium ascorbate, and a Zhidkii Dym Delikaroma smoking flavor (SF) (AO Virteks, Novosibirsk, Russia) containing 3.0–4.0% of phenolic compounds in terms of guaiacol and 8.0–9.0% of organic acids in terms of acetic acid were used as antioxidants.

## MEASURING TECHNIQUES

The *chemical composition*—the weight fraction of proteins, fats, and ashes—was determined using conventional reference methods.

The *fractional composition of proteins of WGFs* was found using the Ermakov's method based on the sequential extraction of proteins with ice water, a 5.0% $K_2SO_4$ solution, a 70.0% ethanol solution, and a 0.2% NaOH solution. At each stage, a weighed portion of 2.5 g was exposed to the solvent two times [26]. At each of the stages, the liquid portion was separated by centrifugation at 5000 rpm for 10 min. The amount of proteins in the solution was determined by the Kjeldahl method. To specify the amount of glutelins after the extraction of albumins and globulins, a joint extraction of prolamins and glutelins with a 0.2% NaOH solution was conducted with the subsequent precipitation of glutelin at a pH of 10.0 in the presence of NaCl [27].

The *solubility of proteins of WGFs* was determined by a modified Betschart method [28]. To this end, a weighed portion of 1 g was mixed with distilled water and the pH of the suspension was adjusted to a value of 2.0–9.0 by adding 1.0, 0.1, or 0.01 N NaOH or HCl. The suspension was thoroughly mixed for 30 min, centrifuged at 5000 rpm for 15 min, and filtered through a paper filter. The amount of dissolved nitrogen was determined by the Kjeldahl method. The solubility of proteins of WGFs was calculated as the ratio of the dissolved nitrogen to the total amount. The *reduced glutathione content* was found by a method based on the oxidation of glutathione with iodine.

The *total content of pentosans* was determined by the colorimetric method after the prehydrolysis of a weighed portion of 0.2 N HCL at 100°C for 150 min and a yeast suspension. The absorbance at a wavelength of 580 and 670 nm was measured using an SF PE-5400UF spectrophotometer [29]. The active acidity (pH) was found by a potentiometric method using a 150-M digital pH meter or an ELWRO 5170 pH meter in the case of the aqueous extract and an ELWRO 5123 portable pH meter equipped with a combined electrode in the case of the meat feedstock. The WBC of the ground meat was determined by centrifugation according to the technique of Wierbicki et al. [30].

The *oxidative deterioration of lipids* in the model systems was found through the determination of peroxide number (PN) according to a standard technique [31] using a chloroform extract prepared by the Piulskaya's method [32] and the determination of thiobarbituric acid number (TBN) by a modified distillation method of Tarladgis using a sulfanilic reagent [33].

## RESULTS AND DISCUSSION

### *Chemical Composition and Properties of WGFs*

The study of the chemical composition of wheat germ included the determination of the main components and their fractional composition. According to the findings, the average protein content in the test germ was 32.8 ± 0.3%. Highly functional albumins and globulins comprise 52.9–63.4% of this amount; albumins compose a major protein fraction, which accounts for an average value of 39.8% of the total number of proteins. The average amount of proteins extracted by 70% ethanol (prolamins) and alkali (glutelins) is 10.2 and 17.8%, respectively. The amount of proteins in the insoluble precipitate that cannot be extracted by the adopted system of solvents was 13.8%.

One of the most important nonprotein nitrogen-containing compounds of plant cells is glutathione; it is a biological reducing agent capable of participating in enzymatic and nonenzymatic reactions that reduce the toxicity of free radicals and peroxides and in metmyoglobin reduction reactions. These properties are very important in terms of stability of the lipid fraction and the color intensity and stability in products during storage. According to the findings, the content of reduced glutathione in WGFs is 0.52 ± 0.03%. These data characterize WGFs as a raw material with a high content of the reducing agent.

Some carbohydrates are technologically significant in the manufacture of meat products; their concentration in WGFs was experimentally determined. Thus, the content of mono- and disugars is 14.1–18.8% in terms of glucose, including the amount of reducing sugars that contribute to a more complete involvement of heme pigments into the color formation reaction, a decrease in the amount of metpigments and nonheme iron from 0 8 to 0.3%. The amount of polysaccharides that, along with muscle proteins, can participate in the formation and stabilization of the structure of meat products has been found. These polysaccharides include cellular tissue (celluloses), which gets into the germ with bran components, nonstarch polysaccharides pentosans, and starches. According to the findings, the weight fraction of cellulose is 2.40 ± 0.04%; insoluble pentosans, 3.9–4.2%; and starch, 6.2 ± 0.3%.

For the studied WGFs, in the case of using diethyl ether as a solvent, the average amount of extractable lipids was 11.72 ± 0.14%, which is equal to their concentration in semi-skimmed soy flour. The average weight fraction of mineral components is 3.95 ± 0.37%. It was experimentally found that the weight fraction of moisture in wheat germ varies from 9.7 to 10.5% with an average value of 10.1%.

According to the findings, wheat germ can be classified as a protein–carbohydrate feedstock with a high content of technologically significant components and lipids.

The dependence of solubility of proteins of WGFs in a pH range of 2.0–9.0 has been determined. The minimum solubility is found in a pH range of 2.0–5.0 (18–36%) with an extremum at a pH of 3.0 (16%). As the acidity of the medium decreases, the amount of extractable proteins gradually increases and achieves a maximum value at a pH of 7.0–8.0 (43–45%). The dependence of protein solubility in a sodium chloride (NaCl) concentration range of 0–12% is as follows. The maximum solubility (42–48%) is observed as the sodium chloride concentration increases from the minimal value to 2.0%. At a reagent concentration of 2.0–8.0%, the solubility of proteins continuously decreases and achieves a value of 31.0%. An increase in the NaCl concentration from 8.0 to 12.0% leads to an increase in the solubility to 37.0%.

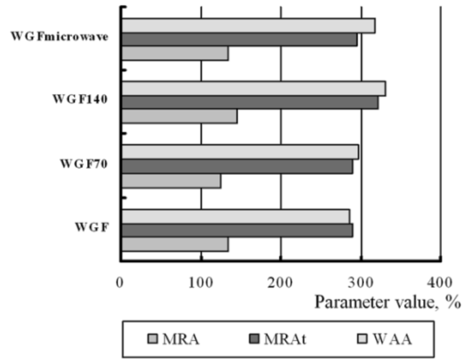
These data suggest that the proteins of WGFs will exhibit high functional properties in meat systems.

*Functional and Technological Properties of WGFs*

The moisture-retaining ability (MRA) and fat-retaining ability (FRA) of WGFs, including hydrated WGFs subjected to heat treatment to a temperature of cooking doneness of meat products ($MRA_t$, $FRA_t$), have been studied.

According to the findings, the water absorbing ability (WAA) of the wheat germ subjected to a high-temperature heating (140°C, 15 min) is 315–340%, while the average WAA of the native germ is 303%; this can be primarily attributed to an increase in the porosity of the structure with increasing internal specific surface area of the capillaries. This assumption is supported by the results of determination of MRA, which increases by 12% relative to the estimate for the native germ. A possible cause of an increase in the WAA can be a thermal modification of the starch.

These data are consistent with the results of determination of WAA and MRA for the flakes subjected to microwave heating and heating at 70°C in which, owing to gentle treatment, the carbohydrate component does not change; at the same time, proteins do not undergo significant denaturation after the microwave treatment either. Therefore, the MRA remains at a level of nontoasted flakes, while the WAA slightly increases, which can be attributed to an increase in the rate of diffusion of moisture owing to a decrease in the water content in the flakes.



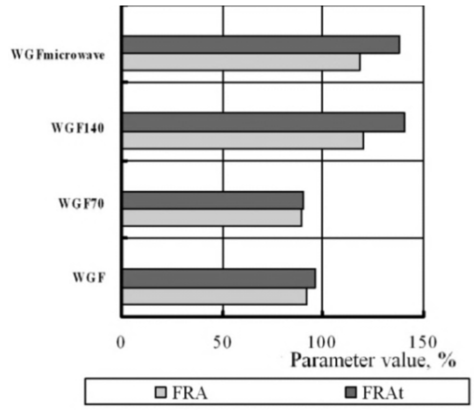




**Fig. 1. Functional and technological properties of WGFs as a function of pretreatment method.**

The MRA of WGFs increases during heat treatment, which should be attributed to the gelatinization of the compactly arranged starch and the dissolution of carbohydrates of the intercellular space, which stimulate osmotic processes through cell walls.

The method of heat pretreatment of WGFs does not have a significant effect on the value of fat absorbing ability (FAA), which remains in a range of 130 ± 5%.

*Effect of WGFs on the Functional Properties of Ground Meat Systems*

Figures 2 and 3 show results of studying the effect of the level of introduction of native WGFs on the pH and WBC of combined ground meat systems prepared of meat feedstock with the different nature of autolysis.

The data suggest that the introduction of wheat germ into ground meat systems based on the feedstock of any of the quality groups leads to an increase in pH. In addition, the maximum effect is revealed for the ground meat system based on PSE pork: the addition of 5.0% of

WGFs to this system leads to an increase in pH by 0.14 units; with a further increase in the level of introduction of wheat germ, the pH value increases by 0.08 and 0.06 units, respectively.

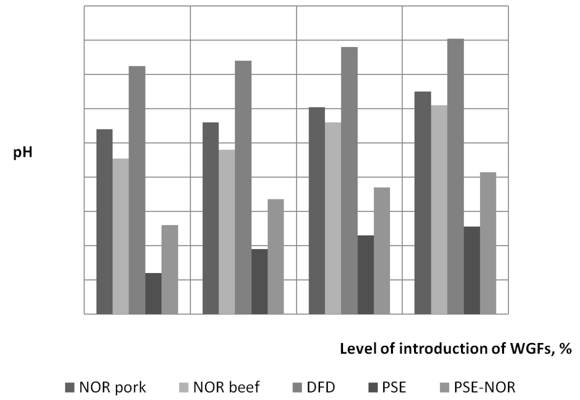



**Fig. 2. Effect of the level of introduction of WGFs on the pH of systems prepared of meat feedstocks of the different quality groups.**

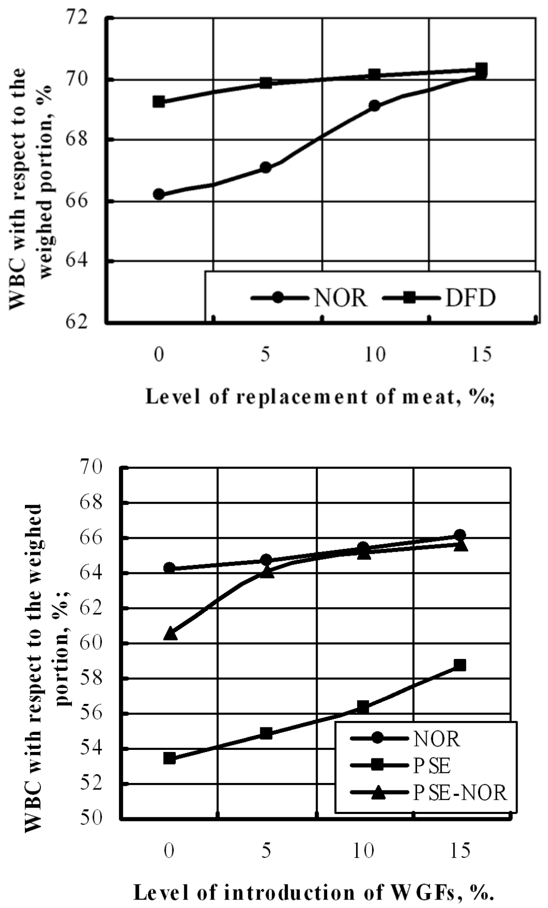



**Fig. 3. Effect of the level of introduction of WGFs on the WBC of the combined systems.**

Changes in the pH of the combined systems have a positive effect on their WBC value, which increases with increasing level of introduction of WGFs regardless of the type and quality group of feedstock, particularly for systems prepared of an exudative PSE material. At the same time, the ground meat systems based on the feedstock with a normal autolysis (NOR beef, NOR pork) and dark, firm, and dry meat (DFD beef) exhibit a tendency to increase the parameter rather than a significant gain in WBC.

The total effect of concentration and state of the functional proteins of the muscle portion of the ground meat system and technologically active components of WGFs can lead to a greater or lesser effect of retaining the moisture and fat during the heating of the system to the temperature of cooking doneness.

Results of determination of the functional and technological properties that characterize the resistance of systems to heating depending on the studied factors are shown in Table 1. According to the findings, combined systems with native WGFs are more stable during heat treatment than pure ground meat systems; a reliable increase in the stability of the ground meat systems is observed in the case of replacement of 10.0% of meat with wheat germ.

**Table 1. Effect of the level of replacement of meat with native WGFs on the functional and technological properties of systems subjected to heat treatment**

| Weight fraction of components | Weight fraction of moisture, % | MRA with respect to moisture, % | Weight fraction of fat, % | FRA with respect to fat, % | Stability of systems, % |
|---|---|---|---|---|---|
| ground meat system based on semifat pork | | | | | |
| 100 : 0 | 60.32 | 75.46 | 23.71 | 54.98 | 75.10 |
| 95 : 5 | 61.65 | 76.85 | 22.57 | 55.44 | 76.42 |
| 90 : 10 | 62.46 | 81.64 | 21.22 | 62.73 | 82.04 |
| 85 : 15 | 62.87 | 85.92 | 20.02 | 68.47 | 85.99 |
| ground meat system based on semifat pork and first-grade beef | | | | | |
| 50 : 50 : 0 | 66.52 | 79.84 | 12.35 | 72.69 | 76.49 |
| 50 : 45 : 5 | 67.19 | 81.07 | 10.47 | 78.24 | 79.05 |
| 50 : 40 : 10 | 67.28 | 84.76 | 10.22 | 80.74 | 84.34 |
| 50 : 35 : 15 | 68.03 | 86.32 | 9.64 | 93.89 | 91.17 |

The stability of a ground meat system is achieved owing to the retention of both moisture and fat in the system, as evidenced by the results of determination of MRA and FRA. In particular, in the case of replacement of 10.0% of semifat pork with WGFs, MRA and FRA of the system increase by 8.19 and 14.10%, respectively. These data suggest that the protein and carbohydrate fractions of wheat germ are involved in the stabilization of the functional and technological properties of the systems. At the same time, it should be noted that the stability of combined systems decreases with increasing weight fraction of fat.

*Stability of the Lipid Fraction of Combined Systems*

The dynamics of primary and secondary oxidation products in the ground meat systems with toasted WGFs and the effect of various food supplements on the stability of the lipid component of the combined systems have been studied.

Results of determination of the PN of the combined ground meat systems with toasted WGFs are shown in Fig. 4. It is found that the heating pretreatment of WGFs is a fairly efficient method for inhibiting the oxidation of lipids of raw ground meat. However, in the absence of antioxidants, oxidation in the systems with WGFs occurs faster than in a pure ground meat system (reference system), which suggests that it is necessary to use supplements exhibiting antioxidant activity.

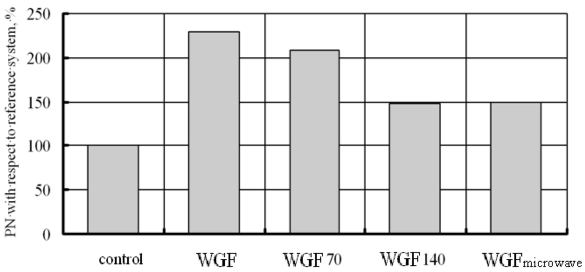



**Fig. 4. PN ratio between the reference system and the combined systems with WGFs.**

The supplements used in this study were a phosphate compound based on trisodium polyphosphate, sodium ascorbate, and an SF.

**Table 2 Effect of Bioton Fos K-144 on the stability of the combined systems**

| Model system composition | PN with respect to reference system, % | 570 nm/650 nm absorbance ratio |
|---|---|---|
| Reference system (without WGFs and phosphate) | 100 | 1.92 |
| Combined system with native WGFs | 225 | 1.65 |
| Combined system with native WGFs and 0.3% phosphate | 229 | 1.62 |
| Combined system with native WGFs, 0.3% phosphate, and 0.05 % sodium ascorbate | 218 | 1.68 |
| Combined system with $WGFs_{140°C, 15}$ | 148 | 1.74 |
| Combined system with $WGFs_{140°C, 15}$ and 0.3% phosphate | 145 | 1.63 |
| Combined system with $WGFs_{140°C, 15}$, 0.3% phosphate, and 0.05 % sodium ascorbate | 140 | 1.81 |

The experimental data (Table 2) show that the introduction of 0.3% of a Bioton Fos K-144 phosphate supplement into the combined system has not led to the inhibition of oxidation. Moreover, the PN of the system with native WGFs in the presence of the phosphate has increased by a factor of 2.3 compared to the reference system, while in the system with native WGFs without phosphates, it has increased by a factor of 2.25, which can be attributed to the catalyzing action of the alkali phosphate on the wheat germ lipoxygenase. This is consistent with the results of determination of the level of oxidation in the combined system with toasted WGFs containing partially inactivated lipoxygenase. According to the findings, the PN has increased by a factor of 1.48 and 1.45 for the combined systems with $WGFs_{140°C, 15}$ without and with phosphate, respectively.

A possible cause of the process acceleration can be the formation of meat metpigments ($Fe^{3+}$) exhibiting high prooxidant action, which can have an additional initiating effect against the background of accumulation of hydroperoxide s as active oxidants.

To verify this assumption, we experimentally studied model systems admixed, along with WGFs and phosphate, with sodium ascorbate as a reducing agent of pigments. In this case, the 570 nm/650 nm absorbance ratio of acetone extracts of heme pigments, as a ratio of the reduced and oxidized forms of the pigments, was determined for all the systems.

The research results suggest that the use of tripolyphosphate in combined systems with native WGFs is inappropriate because of its prooxidant action. The use of this compound in combined systems with toasted WGFs in conjunction with sodium ascorbate contributes to the inhibition of the process; at the same time, this does not provide a reliable stabilization of the lipid fraction.

Inhibition of the accumulation of primary and secondary oxidation products is achieved through the introduction of a Delikaroma SF into the system with WGFs (Fig. 5).

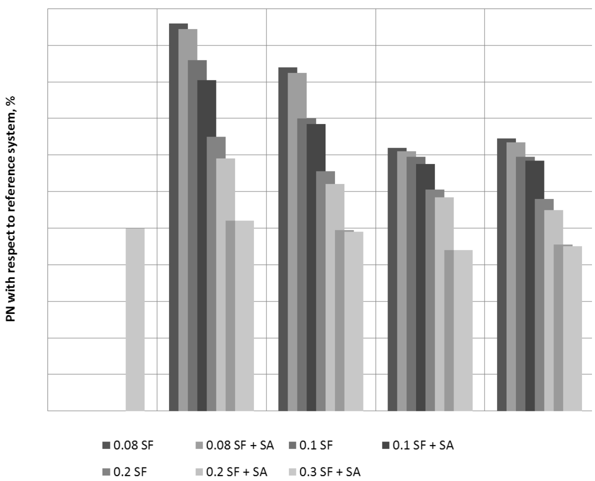



**Fig. 5. Effect of the Delikaroma SF concentration on the oxidation of the lipid fraction of the combined systems.**

Based on the findings, we can state that the mechanism of action of the SF on the oxidation of fats does not change upon the introduction of the SF into systems with different concentrations of primary oxidation products as oxidation catalysts. Inhibition of the process occurs owing to the oxidation chain termination and the binding of free radicals with phenolic compounds having a more mobile proton to form stable products incapable of continuing the free radical oxidation process. Since the oxidation process is developing, a high concentration of inhibitors as free radical traps is required; therefore, the efficiency of action of the SF increases with increasing concentration. In the case of a joint use of the SF and ascorbic acid, a synergetic effect is observed. The SF concentration of 0.3% with respect to the weight of the feedstock is sufficient for effective inhibition of oxidation.

Results of determination of the amount of primary and secondary oxidation products and free fatty acids in cooked systems with SF and differently processed WGFs during refrigerated storage are shown in Table 3.

**Table 3. Parameters of storage stability (at 4 ± 2°C) of the fat phase of combined systems with WGFs subjected to heat treatment to a temperature of cooking doneness**

| Research object | Storage time, days | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | 1 | | | 2 | | | 3 | | | 4 | | |
| | PN | TBN | AN | PN | TBN | AN | PN | TBN | AN | PN | TBN | AN | PN | TBN | AN |
| Reference system | 6.08 | - | 2.1 | 6.08 | 1.12 | 2.4 | 7.02 | 2.12 | 3.8 | 7.02 | 2.75 | 3.9 | 7.56 | 3.53 | 4.1 |
| Combined systems with: native WGFs | 6.47 | - | 2.7 | 7.18 | 1.25 | 31. | 9.28 | 2.37 | 3.8 | 9.12 | 2.92 | 3.8 | 10.61 | 3.60 | 4.1 |
| $WGFs_{70°C, 30}$ | 6.55 | - | 2.1 | 6.24 | 1.09 | 2.2 | 6.40 | 2.01 | 3.1 | 6.63 | 2.54 | 3.4 | 7.49 | 3.26 | 3.4 |
| $WGFs_{140°C, 15}$ | 5.85 | | 2.2 | 6.00 | 0.97 | 2.4 | 6.00 | 1.75 | 2.8 | 6.24 | 2.45 | 3.2 | 7.02 | 3.04 | 3.7 |
| $WGFs_{microwave}$ | 5.69 | | 2.2 | 5.85 | 1.86 | 2.2 | 6.24 | 1.64 | 2.6 | 6.32 | 2.34 | 3.1 | 6.94 | 2.90 | 3.5 |

Note: PN, mmol of active oxygen per kilogram of fat; TBN, mg/1000 g of product; and AN, mg KOH.

The data suggest that the SF has an inhibiting effect on the systems with toasted WGFs under conditions of refrigerated storage for a time corresponding to the shelf life of cooked sausages and prevents the development of a typical defect that is referred to as "the smell of excessively overcooked meat."

Results of the study allow us to recommend the use of WGFs in the technology of cooked sausage products. The flakes should be preheated at 140°C for 15 min. The use of 10% of pretoasted WGFs provides a reliable improvement of the functional and technological properties of combined systems. The stabilization of the lipid fraction is achieved through the simultaneous introduction of 0.3% of a Delikaroma SF into the systems.

## REFERENCES


1. Krylova, V.B., Chechevitsa **-** istochnik pishchevogo rastitel'nogo syr'ya (Lentils as a source of edible plant raw material), *Vestnik Rossiiskoi Aakademii Sel'skokhozyaistvennykh Nauk (Bulletin of the Russian Academy of Agricultural Sciences*), 1994, no. 2, pp. 21–22.

2. Suhaila, M., Jamilah, B., Norhashima, H., and Abd, H., Differences in functional properties of mungbean protein concentrate and the effect of incorporation into fish sausages, *Pertanika Journal of Tropical Agricultural Science,* 1996, vol. 19, no. 1, pp. 69–75.

3. Gorlov, I.F., Shindyalova, E.V., and Sapozhnikova, L.G., Novaya vysoko-belkovaya dobavka iz nuta (A new high-protein supplement of chickpeas), *Myasnaya Industriya* (*Meat Industry*), 1999, no. 6, pp. 24–25.

4. Mizubuti , I.Y., Biondo, O., Jr. Souza, L.W.O., da Silva, R.S.S.F., and Ida, E.I., Functional properties and protein concentrate of Pigeon pea (Cajanus cajan (I.) Millsp) flour, *Archivos Latinoamericanos de Nutricion*, 2000, vol. 50, no. 3, pp. 274–280.

5. Kolpakova, V.V., Martynova, I.V., Severinenko, S.M., Nechaev, A.P., and Berman, Yu.K., Belok iz pshenichnykh otrubei: Proektirovanie sbalansirovannogo sostava pishchevykh kompozitov belkovo-zhirovoi prirody (Wheat bran protein: Formulation of a balanced composition of protein–fatty food composites), *Khranenie i Pererabotka Sel'khozsyr'ya* (*Storage and Processing of Agricultural Raw Materials*), 2001, no. 11, pp. 42–47.

6. Chandi, G.K. and Sogi, D.S., Functional properties of rice bran protein concentrates, *Journal of Food Engineering,* 2007, vol. 79, pp. 592–597.

7. Venkatachalam, M. and Sathe, S.K., Chemical composition of selected edible nut seeds, *Journal of Agricultural and Food Chemistry,* 2006, vol. 54, no. 13, pp. 4705–4714.

8. Ahmedna, Yu. J. and Goktepe, I., Peanut protein concentrate: Production and functional properties as affected by processing, *Food Chemistry,* 2007, vol. 103, pp. 121–129.

9. Sze-Tao, K. and Sathe, S., Functional properties and in vitro digestibility of almond (Prunus dulcis L.) protein isolate, *Food Chemistry,* 2000, vol. 69, pp. 153–160.

10. Olatidoye. O.P., Sobowale, S.S., Akinlotan, J.V., and Olorode, O.O., Chemical composition and physicochemical characteristics of tropical almond nuts (terminalia catappia l) cultivated in South West Nigeria, *Journal of Medical and Applied Biosciences,* 2011, vol. 2.

11. Mao, X. and Hua, Y., Composition, structure and functional properties of protein concentrates and isolates produced from walnut (Juglans regia L.), *International Journal of Molecular Sciences,* 2012, vol. 13, no. 2, pp. 1561–1581.

12. Pankrushina, A.N., Grigor'eva, A.L., Pakhomov, P.M., and Steblinin, A.N., Izuchenie soderzhaniya belka v l'nyanykh zhmykhakh i produktakh ikh pererabotki (A study of the protein content in linseed cakes and their derivatives), *Biomeditsinskie Tekhnologii i Radioelektronika* (*Biomedical Technology and Radioelectronics*), 2005, no. 10, pp. 7–10.

13. Yoshie-Stark, Y., Wada, Y., and Wasche, A., Chemical composition, functional properties, and bioactivities of rapeseed protein isolates, *Food Chemistry,* 2008, vol. 107, pp. 32–39.

14. Mahajan, A. and Dua, S., Salts and pH induced changes in functional properties of amaranth (Amaranthus tricolor L.) seed meal, *Cereal Chemistry,* 2002, vol. 79, no. 6, pp. 834–837.

15. Koz'mina, N.P., *Biokhimiya zerna i produktov ego pererabotki* (Biochemistry of Grain and Its Derivatives), Moscow: Kolos, 1976.

16. Lasztity, R., *The Chemistry of Cereal Proteins,* Boca Raton, FL: CRC Press, 1984, p. 3.

17. Safronova, A.M., Vysotskii, B.G., Narodetskaya, R.V., Trushina, E.N., et al., Pishchevaya tsennost' khlop'ev pshenichnogo zarodysha (Nutritional value of wheat germ flakes), *Voprosy Pitaniya* (*Nutritional Issues*), 1990, no. 3, pp. 54–58.

18. Vishnyakov, A.B., Vlasov, V.N., Novitskii, O.A., and Babenko, I.P., Kompleksnaya pererabotka pshenitsy s polucheniem biologicheski aktivnykh produktov (Integrated processing of wheat to produce biologically active products), *Khranenie i Pererabotka Zerna* (*Grain Storage and Processing*), 2000, no. 12, pp. 52–58.

19. Oufnac, D.S., Determination of antioxidant capacity in corn germ, wheat germ and wheat bran using solvent and microwave-assisted solvent extraction, *B.S. Culinary Arts Thesis,* Thibodaux: Nicholls State University, 2006.

20. Zherebtov, N.A., Zyablova, T.V., and Cheremushkina, I.V., Vliyanie pH i temperatury na aktivnost' i ustoichivost' lipoksigenazy zarodyshei zerna pshenitsy (Effect of pH and temperature on the activity and stability of wheat germ lipoxygenase), *Khranenie i Pererabotka Sel'khozsyr'ya* (*Storage and Processing of Agricultural Raw Materials*), 2000, no. 1, pp. 53–55.

21. Sudha, M.L., Srivastava, A.K., and Leelavathi, K., Studies on pasting and structural characteristics of thermally treated wheat germ, *European Food Research and Technology,* 2007, vol. 225, pp. 351–357.

22. Tarladgis, B.G., An hypothesis for the mechanism of heme catalyzed lipid oxidation in animal tissues, *Journal of the American Oil Chemists Society,* 1961, vol. 38, pp. 479–483.

23. Ramadan, M.F., Showky, H.E.S., and Sulieman, A.E.R.M., Comparison between the effect of γ-irradiation and roasting on the profile and antioxidant activity of wheat germ lipids, *Grasas y Aceities,* 2008, vol. 59, no. 2, pp. 166–173.

24. Pitebskaya, V.S., Shabalta, O.M., Kochegura, A.V., and Zelentsov, S.V., Povyshenie biologicheskoi tsennosti semyan soi pishchevogo naznacheniya (Improvement of the biological value of edible soybean seeds), *Izvestiya Vysshikh Uchebnykh Zavedenii, Pishchevaya Tekhnologiya* (*Transactions of Higher Educational Institutions, Food Technology*), 1997, nos. 2–3, pp. 19–22.

25. Lisitsyn, A.N., Klyuchkin, V.V., and Grigor'ev, V.N., Izuchenie vliyaniya SVCh-nagreva na aktivnost' nekotorykh fermentov (A study of the effect of microwave heating on the activity of some enzymes), *Izvestiya Vysshikh Uchebnykh Zavedenii, Pishchevaya Tekhnologiya* (*Transactions of Higher Educational Institutions, Food Technology*), 1998, no. 3, pp. 12–17.

26. Mineev, V.G., Sychev, V.G., Amel'yanchik, O.A., Bolysheva, T.N., Gomonova, N.F., et al., *Praktikum po agrokhimii: Uchebnoe posobie* (Handbook of Agricultural Chemistry), Moscow: Mosk. Gos. Univ., 2001, 2nd ed.

27. Savai, H. and Morita, V., Studies of rise glutelin: 1. Isolation and purification of glutelin from rise endosperm, *Agricultural and Biological Chemistry,* 1968, vol. 32, pp. 76–80.

28. Betshart, A.A., Nitrogen solubility of alfalfa protein concentrate as influenced by various factors, *Journal of Food Science,* 1974, vol. 39, pp. 1110–1115.

29.Delcour, J.A., Vanhamel, S., and De Geest, C., Physico-chemical and functional properties of rye nonstarch polysaccharides: 1. Colorimetric analysis of pentosans and their relative monosaccharide compositions in fractionated (milled) rye products, *Cereal Chemistry,* 1989, vol. 66, no. 2, pp. 107–111.

30. Wierbicki, E. and Deatherage, F.E., Determination of waterholding capacity of fresh meats, *Journal of Agricultural and Food Chemistry,* 1958, vol. 6, no. 5, pp. 397–392.

31. *GOST* (State Standard) *R 51 487: Masla rastitel'nye i zhiry zhivotnye. Metod opredeleniya perekisnogo chisla* (Vegetable oils and animal fats: A method for the determination of peroxide number).

32. Piul'skaya, V., Ekspress-metod ekstragirovaniya zhira iz zhirovoi tkani (A rapid method for the extraction of fat from adipose tissues), *Myasnaya Industriya SSSR* (*Meat Industry of the Soviet Union*), 1958, no. 1, p. 9.

33. Tarladgis, B.G., Watts, B.M, Yonathan, M., and Dugan, L.R., Jr., A distillation method for the quantitative determination of malonaldehyde in rancid foods, *Journal of the American Oil Chemists Society,* 1960, vol. 37, no. 1, pp. 44–48.