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QUALITY CONTROL METHODS OF SHORTCRUST BISCUITS USING HIGHLY NON-TRADITIONAL RAW MATERIALS

Abstract

Butter cookies refer to products obtained on the basis of visco-plastic dough, which is characterized by a significant amount of fat components, sugar, and the use of wheat flour with an average gluten content. Such a formulation makes the finished product high-calorie and low biological value. The results of research aimed at enriching butter cookies by replacing wheat flour with amaranth flour and a mixture of sprouted cereals with simultaneous regulation of its sugar content by introducing polydextrose are presented in the article. Based on theoretical and experimental studies, it was established that the addition of amaranth flour contributed to the development of springy deformations in the dough and reduced the development of plastic deformations, led to friability, which is associated with a decrease in the content of gluten proteins, the heterogeneity of starch grains, including a significant increase in the amylopectin fraction of starch. It was found that maximum possible replacement was 50% of wheat flour with amaranth flour, which did not impair the taste and aroma of the finished product, but coused dark color both of the dough and the finished product. More amount of replacement of wheat flour with a crushed mixture of sprouted cereals deepened the negative effect on the structural and mechanical properties of the dough, namely, the general deformation of the samples increased, the relative plasticity decreased, and the relative springiness increased. Such regularities are caused by the introduction of a significant amount of dietary fibers into the mixture, as well as low molecular weight water-soluble compounds accumulated due to hydrolytic processes during germination. In the finished products, the baking index increased, there was also an increase in friability. The possibility of adding polydextrose to replace 50% of powdered sugar was experimentally confirmed to improve the structural and mechanical characteristics of dough based on a mixture of amaranth flour, germinated cereal and wheat flour, but the effect on the plastic characteristics of such a replacement was insignificant. In order to achieve the necessary quality indicators, it was proposed to introduce the cellulolytic enzyme preparation Alhamalt HCF from the manufacturer "Stern Ingredients" LLC. It was established that significant changes occurred in the consistency of the dough that was left to rest at a temperature of 35°C, it acquired the plasticity necessary for forming, did not tear, the dough blanks were not characterized by deformation of the seams, and the finished cookies had a smooth, uncracked surface. In the technological scheme for the production of butter cookies with a high content of non-traditional raw materials, it was proposed to introduce a dough resting stage with a temperature of 35 °C, which will allow the enzymatic hydrolysis of cellulose and its derivatives under the action of the introduced enzyme preparation, increase the accumulation of water-soluble sugars, which will lead to the plasticization of the semi-finished product.

Key words: biscuits, amaranth flour, polydextrose, sprouted cereal mix, biscuit structure, plasticity and enzymes.

Introduction

Biscuits are made highly plastic dough, characterised by a high fat content, sugar and wheat flour with a medium gluten content. Thanks to this recipe, finished products are high calorie and, as a rule, have a low biological value. That's why scientists have paid much attention to improving biscuit recipes by introducing raw materials characterised by high content of bioactive substances.

The replacement a wheat flour by other types, as well as non-traditional flour, thus reducing the deficiency in important macro- and microelements, essential ingredients and vitamins, could be one way to improve the nutritional composition. [2]. In our opinion, replacing wheat flour with amaranth flour, one promising area research is a valuable source vitamins B1 and B2 A, E, C, magnesium, squalene, linoleic acid, choline, phospholipids, and a high content of vegetable protein well-balanced in amino acid composition and with a high lysine content [1-2, 4-6]. Nowadays, technologies to produce flour confectionery products using amaranth flour have been mostly improved abroad [3]. However, domestic confectionery industry uses this raw material component only limitedly. Scientists have studied the possibility using finely dispersed amaranth flour in cookies at 30% to replace wheat flour, but higher amounts cause discrepancies in the dough's structural and mechanical properties and complicate how dough pieces are formed. To use higher concentrations, there is a need to select special technological techniques and modes.

A further promising enrichment can be seen to include a finely dispersed mixture of sprouted cereal grains (oats, barley, wheat, corn) as source for not only vitamins and minerals, but also polyphenolic compounds, essential amino acids, dietary fibre, and enzyme complex, which are available in the retail network and are positioned as raw materials having a valuable chemical composition. Combined to amaranth flour, a significant improvement in the physiological content of biscuits can be achieved.

An important issue is to adjust the recipe content is white sugar, because it has an adverse effect to the human body. As sugar in biscuit recipes affects the structural and mechanical characteristics dough, its content is often overestimated. We believe that partial sugar should be replaced by water-soluble dietary fibre polydextrose, characterised as a bulk filler with lower calorie and glycemic content. Polydextrose has been successfully used to partially replace sugar in the technologies of certain groups of sugary confectionery products [7-13].

So, the idea to enrich biscuits by replacing wheat flour and amaranth flour with a mix of sprouted cereals and simultaneously adjusting their sugar content by adding polydextrose is an interesting scientific and practice task.

Literary review

Biscuits are products with a coagulated crystalline structure and are made from dough with plastic and viscous properties. This structure can be achieved at the main stage of the technological process - the dough kneading stage. The dough for biscuits has a complex structure consisting in three phases: solid, liquid and gaseous, the solid phase being the dominant one. The solid phase is represented by particles for flour, starch, dried milk products or cocoa powder (if available), sugar and vanilla powder crystals and other bulk ingredients. The liquid phase is a complex emulsion mixture fat and water available due to the moisture content the ingredients have or due to the recipe using a small amount to adjust the structure a dough. The liquid phase includes partially dissolved sucrose and mélange. The gaseous phase is represented by air bubbles trapped during the whipping process of the fat emulsion and can be saturated with carbon dioxide released by the reaction by sodium bicarbonate with the acidic dough environment if a chemical leavening agents are present in the system.

The structural and mechanical properties dough may vary depending upon the set dough ingredients, their ratio, and the conditions for dough formation, but it must retain its plasticity, take and retain the shape it is given. The process of kneading the dough is carried out in such a way as to preve.

Dough kneading is carried out in such a way as to prevent the development of a gluten backbone. For this reason, low temperatures (23...25 °C) and short kneading times are used.

Hydrophilic properties are a key factor during dough formation. It has been reported that the bulk (85%) the dough moisture is bound by the main components the flour, proteins and starch [14-18]. The hydration process for starch and proteins, however, is not the same. While kneading the dough, starch binds water faster than protein. Starch grains bind water mainly by adsorption (surface), and to a lesser extent by microcapillaries. Therefore, when mixing the dough, its volume increases slightly. At the same time, the rate and quantity at which starch grains hydrate depends upon the degree of damage. Intact starch grains absorb a maximum to 0.3 - 0.4 g Water per 1 g dry matter, and damaged grains - 2 - 3 g/g dry matter, i.e. with increasing degree that starch grains are damaged, the water absorption capacity becomes higher. It is believed that wheat flour with good quality should contain no more than 15% damaged starch grains.

Carbohydrates, primarily starch, also make up the bulk (60-65 %) Amaranth flour, but its polygonal granules are extremely small (0.75-3 μm). Amaranth starch granules are formed by branched amylopectin and linear unbranched amylose at a ratio of 20:1 to 10:1 [19]. This is significantly different from wheat flour, whose starch granule size varies from 5-30 microns, and whose amylopectin and amylose ratio is from 4:1 to 3:5. The starch granule size is negatively correlated with the starch gelling temperature, at 66.5-78.4 °C and 54-62 °C for amaranth and wheat flour, respectively [20-21]. Therefore, dough kneading with amaranth flour will differ from that with wheat flour.

Flour proteins are able to absorb water when cold, swelling and absorbing a significant amount of water to form thin films that envelop, bind and glue together the grains of moistened starch. This gluten backbone gives wheat dough a certain viscosity, elasticity and resilience. Therefore, using flour with a high gluten protein content will result in greater water absorption. The water-absorbing capacity of flour depends on the amount and quality of gluten, moisture content, yield and grinding size, which increases by 1.8-1.9% with a 1% decrease in flour moisture content and an increase in flour yield. The larger the flour particles, the smaller their specific surface area and therefore they bind water less.

Water-absorbing capacity is influenced by the sugars and fat in the dough. If you add more sugar to the dough with a constant amount of water, the dehydrating properties of sugar will reduce the amount of colloidally bound water in the dough and increase the amount of free water in the form of sugar solution. This contributes to the dough thinning. It has been found that the water-absorbing capacity of flour decreases by 0.6% with the addition of 1% sugar. Scientists have found that amaranth flour differs from wheat flour in terms of reduced moisture content and increased water absorption capacity [4, 22-23].

Wheat flour pentosans, both water-soluble and water-insoluble, also have a significant impact on its structural and mechanical properties. Their content is 2.1 - 3.4 % in wheat flour. Pentosans absorb water mainly osmotically. Water-soluble pentosans absorb 15 times more water relative to their weight, and insoluble pentosans absorb 10 times more. This helps to increase the viscosity of the dough and improve its plasticity. Amaranth flour also has a high content of soluble and insoluble fibres.

The fibre, included in the shell parts the grain, adsorbs water. It has a 20% higher water binding capacity than flour. Therefore, as the flour yield increases, its water-absorbing capacity increases, but the gluten content decreases, resulting in an excessively crumbly dough that is difficult to mould. This difficulty in moulding is the reason why other types of flour, which are rich in dietary fibre and do not contain gluten proteins, are not used in butter biscuit technology. Chemical structure amaranth flour contains only up to 16% of proteins, which are not capable of forming a gluten backbone, and is also characterised by a low content of dietary fibre (fibre (0.85 g)). That is, significant crumbling may not be observed when amaranth flour is used to replace wheat flour. Such a result was obtained by the authors [24] studying the effect of amaranth flour on the quality of butter biscuits and found that there was a significant deterioration in the wettability of the biscuits, they were characterised by a significant hardness that was unacceptable to the consumer.

A very important role in forming the structure the dough plays fat, and it is included in the composition biscuits in significant quantities. Fats are adsorbed on the surface of proteins and starch grains, preventing the swelling of flour colloids, thus leaving a small amount of free moisture in the dough, which gives the dough its plastic properties. The essential role is played by the triglyceride composition of fats - the more unsaturated fatty acids the fat contains, the better it is absorbed by proteins [25-27]. Replacing part (0.25-6.0%) the fat with phosphatide concentrates helps to create a more plastic dough at the same humidity and temperature.

White sugar is important for dough structure. In an aqueous solution, sucrose molecules are covered with hydrate shells, increasing their intermolecular volume and reducing the rate for diffusion during osmotic swelling by flour proteins. Sucrose molecules are highly hydrated. At 20°C, they bind and retain from 8 to 20 water molecules. Thus, a higher sucrose content in the dough means less free water in the liquid phase, involved in the hydration and swelling effect on flour colloids [28-29]. But excessive sugar in the recipe leads to a rough and hard biscuit structure, due to the crystallisation in the structure the finished product.

So, according to functional and technological indicators, amaranth flour can be recommended for use in biscuit technology to replace wheat flour, but its concentrations should be determined by a set of organoleptic, physicochemical, structural and mechanic product parameters.

Wheat, oats, barley and corn germination mix is designed to enhance the biological properties and improve the digestibility foods. Therefore, a main advantage using mix of sprouted grains is to increase the biological values. Sprouted grains contain an increased content for vitamins, enzymes and antioxidants, thus improving the nutritional value and having a positive impact on health by supporting immunity, reducing the effects on free radicals and improving metabolic processes in the body. The aim of germinating grains is to promote the synthesis and activation enzymes that affect the conversion of complex substances such as starch and protein into simpler components such as maltose, glucose, dextrins, peptides, peptides, amino acids and other compounds. Fermentation also facilitates the conversion of macro- and microelements to forms that are easily absorbed by the body [30-33].

Polydextrose is a soluble artificial polymer that is only partially fermentable by the gut microbiota. Polydextrose is a glucose polymer and is used in the food industry as a sugar and fat substitute. Due to its processing properties, it can give a good structure and sweet taste to products. It has a low glycemic index and an energy value below 1,2…2,4 kcal/g. [34-35]. Improved structural and mechanical properties resulting from polydextrose in confectionery products were observed for jelly and jelly-fruit marmalade with fructose or glucose-fructose syrups, fondant sweets, and foamy structures of decorated semi-finished products. In the technology of flour confectionery products, there is evidence that replacing the 5% flour by polydextrose significantly improves the sugar biscuits' quality indicators, and an additional increase in its content has a negative impact on the quality indicators of finished products [36-37]. Thus, nothing has been studied in detail about the effect of dietary fibre upon the structure of biscuit dough.

Based on the analysis, it can be concluded that all the proposed recipe components will have a significant impact on the quality of dough and the finished product and will require a detailed study regarding changes in the technological process.

Research is focused mainly on the production biscuits using amaranth flour, a mix the sprouted cereals and water-soluble dietary fibre - polydextrose.

Formulation of the problem.

This paper aims to determine the patterns observed in the structural and mechanical characteristics biscuit dough if significant amounts a wheat flour are replaced by amaranth flour, a mix of sprouted cereals, the sugar content is reduced to the point where it provides only a sweet taste, and a water-soluble dietary fibre, polydextrose, is used to replace sugar.

According to the goal, the following objectives were:

1. to determine the effect of amaranth flour, which is used to replace wheat flour in the recipe of butter biscuits, on the quality of the dough; to determine its rational concentrations;
2. to determine the effect of a mixture of sprouted cereals on the structural and mechanical properties of the dough for butter biscuits, to establish the maximum possible recipe amount;
3. to experimentally confirm and establish the maximum possible replacement of powdered sugar with water-soluble dietary fibre - polydextrose;
4. to study the organoleptic, physicochemical and structural-mechanical quality indicators of dough and finished biscuits under the influence of variable factors in the recipe; to provide technological recommendations for improving product quality to meet the requirements of current regulatory documents.

Study object - technology of butter biscuits.

Research subject - amaranth flour, a mix with crushed sprouted grains, water-soluble dietary fibre (polydextrose), structural and mechanical characteristics biscuit dough, organoleptic and physicochemical biscuit quality parameters.

Materials and methods

The following raw materials were used in the study: high-grade wheat flour (GOST 46.004-99); amaranth flour (produced by Organic Oils LLC, Ukraine, Ivano-Frankivsk). Ivano-Frankivsk), powdered sugar (DSTU 4623:2006); butter (DSTU 4399:2005); soda (GOST 2156-76); salt (DSTU 3583:2015); Ammonium carbonate (GOST 9325-79); mix of crushed sprouted cereal grains (produced by Choice LLC, Ukraine, Kyiv); polydextrose (produced in China).

Table 1 – Krymulda recipes table shortbread biscuits (control) and samples

Name	Control	Sample 1	Sample 2	Sample 3	Sample 4
Premium wheat flour	64,8	32,4	10,0	10,0	10,0
Amaranth flour	-	32,4	32,4	32,4	32,4
Mixed sprouted cereals	-	-	22,4	22,4	22,4
Polydextrose	-	-	-	10,7	10,7
Butter	27,5	27,5	27,5	27,5	27,5
Salt	0,24	0,24	0,24	0,24	0,24
Soda	0,37	0,37	0,37	0,37	0,37
Ammonium carbonate	0,177	0,177	0,177	0,177	0,177

Biscuits were prepared based a Krymuldat traditional recipe, the experimental samples were made according to the recipes given in Table 1. Five samples are used in the study:

sample No. 1 (control) – shortbread biscuits recipe, wheat flour 100 %;

Sample No. 2 – wheat flour 50 % + amaranth flour 50 %;

sample No. 3 – wheat flour 15 % + amaranth flour 50 % + mix sprouted cereal grains 35 %;

sample No. 4 – wheat flour 15% + amaranth flour 50% + mix sprouted cereal grains 35% + polydextrose (to replace powdered sugar) 50%.

Our production flow chart was carried out in accordance with the technological instructions for biscuit production [38]. Dough density was determined by a method based on measuring the volume of liquid displaced by immersion of a sample of the test product. The elastic and plastic dough properties were determined using a CT-1 structural tester. The finished product quality was determined in accordance with the requirements of DSTU 3781:2014: mass moisture content – by the method of accelerated drying in the desiccator, wetting – by the ability of the biscuits to absorb moisture for 2 min, in %; baking was characterised by the weight loss during heat treatment, in %.

Results of the study and their discussion

First, we determined the maximum possible amount of wheat flour substitution for amaranth flour. The experimental samples used 30%, 50%, 70%, 100% replacement for wheat flour. It was found that the addition of amaranth flour leads to a change in the organoleptic characteristics of both dough and biscuits. First of all, the dough changes colour towards a deep brown, and its plasticity decreases. The dough acquires a more fragile structure, which is associated with a decrease in the content of gluten proteins, heterogeneity of starch grains, including a significant increase in the amylopectin fraction.

Finished biscuits have also been characterised by darkening, increased fragility structure, characteristic amaranth flavour and aroma. According to the organoleptic parameters, 50% wheat flour was replaced by amaranth flour. Increased dosage for amaranth flour (more than 50%) worsens the organoleptic characteristics of biscuits. The positive aspect is the reduction in mass loss during baking; 50% amaranth flour substitution for wheat flour allows to reduce baking by 19% (16% to 12.8%).

The second stage included further enrichment the chemical composition of biscuits by adding 15% to 50% of a mix containing crushed sprouted barley, wheat, oats and corn to replace wheat flour. Biscuits containing 50% wheat flour and 50% amaranth flour were used as a control sample.

It was found that the addition of a mix the sprouted grains contributes to further darkening dough, it acquires a golden brown colour due to the exclusion a white wheat flour. Similar patterns in changes of organoleptic characteristics are inherent in the baked product: the biscuits acquire a more intense colour and greater crumbliness. However, using a mix of sprouted grains does not affect the aroma and taste of the finished product. The best sample was the one with 35% wheat flour replaced by a mixture sprouted with sprouted grains. The biscuits had a crumbly structure, pleasant taste and aroma. The samples with higher content sprouted grains, namely when wheat flour was completely replaced with a mixture, have an extraneous crunch that gives an unpleasant aftertaste to consumers.

Using sprouted grains increases baking index of the experimental samples, because the mixture contains a significant quantity a low molecular weight water-soluble compounds. Thus, 12.8% baking for the sample without the addition a mixture, and 14.1% for the sample with 35% input. Thus, reducing flour gluten and high molecular weight polysaccharides, including starch, reduces the moisture retention capacity of macromolecules in the dough during baking. Biscuits are obtained with a more crumbly texture compared to traditional products.

In addition, an increased mixture quantity changes the structural and mechanical properties dough, namely, the total sample deformation increases, the relative plasticity decreases and the relative elasticity increases (Table 2).

For example, overall deformation samples with 15% sprouted grain mix increases by 32%; with 35% - by 73%; with 50% sprouted grain mix - by 156%. The relative plasticity increases by 0.7% if 15% sprouted grain mix is added; by 1.2% if 35% sprouted grain mix is added; and by 3% if 50% sprouted grain mix is added. The relative elasticity increases by 37% with 15% mix sprouted grains; by 64% with 35%; and by 164% with 50%.

Table 2 - Texture and mechanical parameters for dough samples

Special features a sample formulation	Overall deformation ΔH_1	Residual plasticity ΔH_2	Elastic deformation ΔH_3	Relative plasticity $\Delta H_{пл}$,%	Relative elasticity, $\Delta H_{пр}$,%
50 % wheat flour, 50 % amaranth flour	2,74	2,69	0,05	98,18	1,82
50 % amaranth flour, 35 % wheat flour, 15 % sprouted grain mix	3,60	3,51	0,09	7,50	2,50
50 % amaranth flour, 15 % wheat flour, 35% sprouted grain mix	4,74	4,60	0,14	97,0	3,0
50 % amaranth flour, 50 % sprouted grain mix	7,02	6,68	0,04	95,2	4,8

These results show a significant change the structural and mechanical properties dough samples containing non-traditional raw materials. The dough will have large losses during dough pieces moulding, making it difficult to form them.

Quality analysis of gluten washed from the experimental samples, Fig. 1, showed that all three types differ significantly from each other: wheat flour gluten structure is elastic, light yellow in colour, has stretchability, and forms a smooth, continuous structure upon forming into a ball.

Amaranth flour gluten is crumbly, creamy in colour. In our opinion, this may be due to the fact that amaranth proteins include a smaller fraction gliadin, giving the gluten its extensibility. Also, amaranth flour dietary fibres, including glucan and hemicellulose, may be included among other things a gluten complex.

Wheat gluten is washed from a sprouted grain mix, but has a crumbly structure that cannot be formed into a single ball and is brown in colour. That is, it does not represent pure washed gluten, but a protein-polysaccharide complex, formed due to protein groups present in cereals, water-insoluble fractions, insoluble polysaccharides, etc.

Changes such as these in the gluten backbone cause different dough structures and consistency in finished products. This explains the dough's darkening colour, as well as its brittle, inelastic structure, and an increase in overall deformation and relative elasticity.

The dough density remained practically unchanged despite the significant changes of structural and mechanical properties but for all the experimental samples it was 1,200 g/cm3. After baking, the biscuit wettability increased from 142% (for the control sample) to 146% (for the sample with 35% of sprouted grains). This confirms our conclusion about the biscuit structure being more fragile, having a higher proportion of micro- and macrocapillaries than traditional products, leading to greater water saturation.

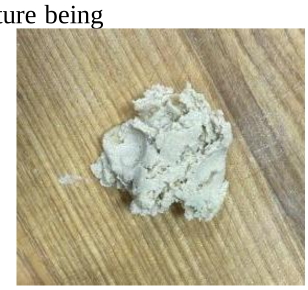
Thus, dough and biscuit texture needs to be adjusted. As mentioned above, one of the possible options for improving the structural and mechanical properties dough is to add the water-soluble polysaccharide poly dextrose. In studying how polydextrose affects the dough, the test samples were formed with 50% replacement and 100% replacement of powdered sugar. The sample with the following flour mixture was chosen as a control: 50% amaranth flour, 15% wheat flour, 35% sprouted cereal grain mix.

Our results showed that the addition the polydextrose does not affect the dough colour, but it does affect the biscuit colour. The biscuits acquire a more even golden brown colour. This is due to an intensification in melanoidin formation, resulting from the baking process due to the interaction between reducing sugars and amino acids. This is due to replacement the sucrose as a non-reducing sugar with polydextrose, a source for additional aldehyde groups. It also improves biscuits' flavour, giving them honey and nutty notes. At the same time, replacing 50% or more sugar with polydextrose significantly reduces the sweetness. That is why the maximum permissible substitution in terms off taste is 50%.

Adding polydextrose to replace sugar also affects the structural and mechanical properties dough, as sugar is directly involved in making dough, Table 3.

Using the polysaccharide polydextrose to replace sucrose disaccharide increases overall dough deformation: by 42% at 50% sugar replacement with polydextrose; by 55% at 100% polydextrose to replace powdered sugar. However, relative plasticity increases slightly: by 0.4% at 50% sugar substitution with polydextrose; by

Wheat flour gluten



Amaranth flour gluten

Mixed sprouted cereal gluten

Fig. 1. Flour raw material gluten

Table 3 - Mechanic and structural properties of dough samples

Sample formulation features	Overall deformation ΔH1	Residual plasticity ΔH2	Elastic deformation ΔH3	Relative plasticity ΔHпл,%	Relative elasticity ΔHпр,%
50 % amaranth flour, 15% wheat flour, 35% sprouted grain mix	5,16	5,10	0,06	98,8%	1,2
50 % amaranth flour, 15% wheat flour, 35% sprouted grain mixture, 50 % polydextrose	7,34	7,28	0,06	99,2	0,8
50% amaranth flour, 15% wheat flour, 35% sprouted grain mixture, 100 % polydextrose	8,00	7,94	0,06	99,3	0,7

0.5% at 100% polydextrose substitution with powdered sugar. At 50% sugar substitution with polydextrose, the relative elasticity decreases by 7% and by 8% at 100% polydextrose substitution with powdered sugar.

Also, adding polydextrose slightly decreases the dough density from 1.206 to 1.200 g/cm^3, and increases the biscuit wettability from 146% (for the control sample) to 156% (for the 100% replacement sample), and increases the baking time from 14.12% to 16.06%.

So, our studies have established the possibility using polydextrose as a water-soluble polysaccharide to improve the structural and mechanical properties dough for biscuits with a high food fibre content. However, such replacement is not enough, as the plastic properties are improved slightly, the dough has a brittle structure, and the finished products have increased crumbliness.

Therefore, following the next stage, research decision was made to improve the structural and mechanical properties dough and biscuits with a high content nutritional fibre by using enzymes. The cellulolytic enzymes Alhamalt HCF from Stern Ingredients, Germany, was chosen for use. Alhamalt HCF is a non-pathogenic, genetically unmodified strain of Trchoderma logibrachiatum (reesei). Standardised pure mushroom hemicellulose. This enzyme can be used in both soluble and insoluble flour pentosans, thereby freeing water from the pentosan gel, leading to an increase in hydration of gluten proteins.

We investigated the enzymes for use in bakery products. It was found that it helps to increase the volume of bakery products by increasing extensibility of strong gluten, increasing the water absorption capacity of dietary fibres, improves the taste of products and extends their shelf life. Based upon the manufacturer's recommendations, it is used in the processing of strong gluten flour and low-grade flour. So far, enzymes has not been used to improve the structure of flour confectionery products. That is why research regarding the ability to improve the structure of biscuit dough with amaranth flour and mix sprouted cereal grains by adding a cellulolytic enzymes is a new direction from a scientific and practical point of view.

Optimal dosage of enzymes, as recommended by the manufacturer, depends upon the flour quality, recipe, structural and mechanical properties dough, baking time and can by 0.1-0.9 g per 100 kg flour.

It was considered necessary to determine the optimal time for the enzymes to be used, since the action of hydrolases is activated with dough proofing. The test samples were proofed for 4 hours at 23°C and 35°C. The 23°C temperature is the average air temperature in the confectionery shop during dough kneading. 35±1°C is the optimum temperature for the action an enzymes. By using these temperatures, enzymes activity was determined by determining changes in the structural and mechanical properties of the dough.

We used 0.9 g for every 100 kg flour, the maxi mum recommended amount, since the dough contains a significant quantity fats and dietary fibres that, in our

Table 4 - Structural and mechanical properties dough with enzymes

Recipe features and composition sample	Overall deformation ΔH1	Residual plasticity ΔH2	Elastic deformation ΔH3	Relative plasticity ΔHпл,%	Relative elasticity ΔHпр,%
Curing at 23 ± 1°C					
After mixing, no proofing	2,63	2,57	0,06	97,7	2,3
After 1 hour proofing	1,99	1,93	0,06	97,0	3,0
After 2 hour proofing	1,60	1,54	0,06	96,3	3,7
After 3 hour proofing	1,45	1,39	0,06	95,9	4,1
Curing at 35±1°C					
After mixing, no proofing	2,41	2,35	0,06	97,5	2,5
After 1 hour proofing	3,20	3,15	0,05	98,4	1,6
After 2 hour proofing	5,85	5,80	0,05	99,1	0,9
After 3 hour proofing	6,41	6,36	0,06	99,2	0,8

opinion, will slow down the enzyme's action. The enzyme was introduced with the flour mix, and after kneading, the dough was placed in a proofing cabinet for proofing at the experimental temperature, measuring structural and mechanical parameters.

Table 4 shows that the total deformation the dough samples with enzymes Alhamalt HCF after an hour of proofing at 23 ± 1°C by 24%; after two hours - by 39%; after three hours - by 44%. The relative plasticity for the sample after one hour curing decreases by 0.9%; after two hours - by 1.7%; after three hours - by 1.9%. The relative elasticity increases by 30% for the sample after an hour of resting; after two hours - by 60%; after three hours - by 78%.

Overall deformation dough samples with Alhamalt HCF enzymes after one hour of proofing at 35±1°C increases by 32%; after two hours - by 142%; after three hours - by 165% Relative plasticity for the sample after one hour of proofing increases by 0.9%; after two hours - by 1.6%; after three hours - by 1.7%. After one hour of curing, the relative elasticity decreases by 36%; after two hours - by 64%; after three hours - by 68%.

At 23°C, there are no significant changes in the structure of the dough, so the enzymes does not show its activity at this temperature. The optimum temperature for enzyme action is 35°C, reflected in the organoleptic properties dough and biscuits. Significant changes occur in the consistency of the dough and finished products. The dough becomes more plastic, does not tear, dough pieces are formed correctly and without seam deformation, and the finished biscuits have a smooth, non-cracked surface.

It has been determined that the density index remains constant and does not depend on the action of the enzymes. However, the main physicochemical parameters of the finished product, such as baking and wettability, change. The baking index decreases from 15.17% to 10.24%, while the wettability decreases from 152% to 146%. Reducing the baking index will lead to an increase of finished product yield, thus positively affecting its cost, and a 4% decrease in the wettability confirms that the structure of dough and biscuits has become more monolithic, cohesive, and less fragile. It predicts a reduction the losses caused by crumbling finished biscuits during packing and packaging.

Therefore, theoretical and experimental studies have been used to determine patterns in the structural and mechanical parameters biscuit dough changes when replacing significant amounts a wheat flour with amaranth flour, sprouted cereal mix, reducing sugar content to the limits that provide only a sweet taste, and using water-soluble dietary fibre - polydextrose - to replace sugar.

Amaranth flour addition has been found to promote elastic deformations in the dough and reduce plastic deformations, leading to crumbling, due to a decrease in gluten proteins, heterogeneity of starch grains, as well as a significant increase in the amylopectin starch fraction. As much as possible, 50% wheat flour can be replaced with amaranth flour, since it does not impair the taste and aroma but gives both the dough and the finished product a dark colour.

Dough further substituted with wheat flour and crushed sprouted cereal mix has a negative effect upon the structural and mechanical properties, namely, an increase in the overall deformation, reduction in relative plasticity, and increase in relative elasticity. Such regularities are caused by the addition a significant amount by dietary fibre mix, as well as low molecular weight water-soluble compounds accumulated due to hydrolytic processes during germination. Baking index of finished products increases, and there is an increase in crumbliness.

Using polydextrose at 50 % powdered sugar to improve the structural and mechanical characteristics dough based on a mix to amaranth flour, sprouted cereal and wheat flour was experimentally confirmed, but the effect on plastic performance was insignificant. It was proposed to introduce the cellulolytic enzymes Alhamalt HCF from Stern Ingredients LLC (Ukraine) in order to achieve the required quality parameters. It was found that significant changes occur to the consistency dough, exposed to proofing at 35°C, it acquires the plasticity necessary for moulding, does not tear, dough pieces are not characterised by seam deformation, and the finished biscuits have a smooth, non-cracked surface.

It is proposed to introduce a dough proofing stage at 35°C in the technological scheme of shortbread biscuits production with a high content a non-traditional raw materials, allowing enzymatic hydrolysis by cellulose and its derivatives under influence of an enzymes, increasing the accumulation a water-soluble sugars, leading to semi-finished product plasticisation.

REFERENCES

1. De Bock, P., Daelemans, L., Selis, L., Raes, K., Vermeir, P., Eeckhout, M., & Van Bockstaele, F. Comparison of the chemical and technological characteristics of wholemeal flours obtained from amaranth (Amaranthus sp.), quinoa (chenopodium quinoa) and buckwheat (fagopyrum sp.) seeds. Foods; 2021
2. Rustagi, S., Khan, S., & Jain, T. (2022). Comparative study of nutritional and functional characteristics of pearl millet, buckwheat, amaranth and unripe banana flours for gluten-free bakery products. *Food Research*, *6*(3), 411-419.
3. Chauhan, A., Saxena, D. C., & Singh, S. (2016). Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies. *Cogent Food & Agriculture*, *2*(1), 1125773.
4. Mykolenko, S., Zhygunov, D., & Rudenko, T. (2021). Baking properties of different amaranth flours as wheat bread ingredients.
5. Siwatch, M., Yadav, R. B., & Yadav, B. S. (2019). Chemical, physicochemical, pasting and microstructural properties of amaranth (Amaranthus hypochondriacus) flour as affected by different processing treatments. *Quality assurance and safety of crops & foods*, *11*(1), 3-13.
6. Malik, M., Sindhu, R., Dhull, S. B., Bou-Mitri, C., Singh, Y., Panwar, S., & Khatkar, B. S. (2023). Nutritional composition, functionality, and processing technologies for amaranth. *Journal of Food Processing and Preservation*, *2023*(1), 1753029.

7. Matyas, D. S. Improving the technology of jelly-fruit marmalade with reduced sugar content: autoref. thesis ... candidate technical sciences: 05.18.01 "Technology of bakery products, confectionery and food concentrates" / Matyas Daria Serhiivna; NUKHT. - K., 2019. – 23 p.
8. Avetisyan, K.V. Improvement of the technology of two-layer jelly marmalade using starch syrups: autoref. thesis ... candidate technical Sciences: spec. 05.18.01 "Technology of bakery products, confectionery and food concentrates" / Karine Valerivna Avetisyan; of science driver K. G. Iorgachova; ONAKHT - Odesa, 2015. - 23 p.
9. 9 Sokolovska, I. O. Rational use of pectin and tritium alginate in the technology of protein creams with reduced sugar content: autoref. thesis ... candidate technical Sciences: spec. 05.18.01 "Technology of bakery products, confectionery and food concentrates" / Iryna Oleksandrivna Sokolovska. - Kyiv, 2015. - 23 p.
10. Veena, N., Nath, S., & Arora, S. (2016). Polydextrose as a functional ingredient and its food applications: a review. *Indian Journal of Dairy Science*, *69*(3), 239-251.
11. Aidoo, R. P., Appah, E., Van Dewalle, D., Afoakwa, E. O., & Dewettinck, K. (2017). Functionality of inulin and polydextrose as sucrose replacers in sugar‐free dark chocolate manufacture–effect of fat content and bulk mixture concentration on rheological, mechanical and melting properties. *International Journal of Food Science & Technology*, *52*(1), 282-290.
12. Maringka, C. T., Putra, A. B. N., & Lo, D. (2024). Development of gummy candy with polydextrose, isomalto-oligosaccharides, fructo-oligosaccharides, and xylitol as sugar replacers. *International Journal of Gastronomy and Food Science*, *35*, 100881.
13. Aidoo, R. P., Afoakwa, E. O., & Dewettinck, K. (2014). Optimization of inulin and polydextrose mixtures as sucrose replacers during sugar-free chocolate manufacture–Rheological, microstructure and physical quality characteristics. *Journal of Food Engineering*, *126*, 35-42.
14. Maache-Rezzoug, Z., Bouvier, J. M., Allaf, K., & Patras, C. (1998). Effect of principal ingredients on rheological behaviour of biscuit dough and on quality of biscuits. *Journal of Food Engineering*, *35*(1), 23-42.
15. Pareyt, B., Brijs, K., & Delcour, J. A. (2009). Sugar-snap cookie dough setting: The impact of sucrose on gluten functionality. *Journal of agricultural and food chemistry*, *57*(17), 7814-7818.
16. Zhang, Z., Fan, X., Yang, X., Li, C., Gilbert, R. G., & Li, E. (2020). Effects of amylose and amylopectin fine structure on sugar-snap cookie dough rheology and cookie quality. *Carbohydrate polymers*, *241*, 116371.
17. Pedersen, L., Kaack, K., Bergsøe, M. N., & Adler-Nissen, J. (2004). Rheological properties of biscuit dough from different cultivars, and relationship to baking characteristics. *Journal of Cereal Science*, *39*(1), 37-46.
18. Dhal, S., Anis, A., Shaikh, H. M., Alhamidi, A., & Pal, K. (2023). Effect of mixing time on properties of whole wheat flour-based cookie doughs and cookies. *Foods*, *12*(5), 941.
19. Amaranth as a rediscovered "new" crop is surging in the recent two decades. The major carbohydrate of some amaranth species is starch which accounts up to around 60% of the dry grains. This review summarizes the present knowledge of the isolation, composition, structure, physiochemical properties, modifications, and applications of amaranth starches, and provides suggestions for research to further improve the utilization.
20. Zhu, F. (2017). Structures, physicochemical properties, and applications of amaranth starch. *Critical reviews in food science and nutrition*, *57*(2), 313-325.
21. Kong, X., Bertoft, E., Bao, J., & Corke, H. (2008). Molecular structure of amylopectin from amaranth starch and its effect on physicochemical properties. *International Journal of Biological Macromolecules*, *43*(4), 377-382.
22. Ayo, J. A. (2001). The effect of amaranth grain flour on the quality of bread. *International Journal of Food Properties*, *4*(2), 341-351.
23. Singh, M., & Liu, S. X. (2021). Evaluation of amaranth flour processing for noodle making. *Journal of food processing and preservation*, *45*(4), e15270.
24. Mykolenko S.Yu. Study of the influence of amaranth and flax flour on the quality of cookies / S.Yu. Mykolenko, A.V. Zakharenko // Technical sciences and technologies. – 2020. – No. 1 (19). – P. 228–240.-Access mode: http://dspace.dsau.dp.ua/jspui/handle/123456789/3369
25. Devi, A., & Khatkar, B. S. (2018). Effects of fatty acids composition and microstructure properties of fats and oils on textural properties of dough and cookie quality. *Journal of food science and technology*, *55*, 321-330.
26. Devi, A., & Khatkar, B. S. (2016). Physicochemical, rheological and functional properties of fats and oils in relation to cookie quality: a review. *Journal of food science and technology*, *53*, 3633-3641.
27. Jacob, J., & Leelavathi, K. (2007). Effect of fat-type on cookie dough and cookie quality. *Journal of food Engineering*, *79*(1), 299-305.
28. Laguna, L., Vallons, K. J., Jurgens, A., & Sanz, T. (2013). Understanding the effect of sugar and sugar replacement in short dough biscuits. *Food and Bioprocess Technology*, *6*, 3143-3154.
29. Kawai, K., Toh, M., & Hagura, Y. (2014). Effect of sugar composition on the water sorption and softening properties of cookie. *Food Chemistry*, *145*, 772-776.
30. Santa Senhofa, T. Ķ., Galoburda, R., Cinkmanis, I., & Martins Sabovics, I. (2016). Effects of germination on chemical composition of hull-less spring cereals. *Research for rural development*, *1*, 91-97.
31. Alshamlan, N. S. (2023). Effect Of Germination Process on Chemical Composition of Barley Grains, Nutritional Value. *Journal of Food and Dairy Sciences*, *14*(1), 1-4.
32. Xu, M., Jin, Z., Simsek, S., Hall, C., Rao, J., & Chen, B. (2019). Effect of germination on the chemical composition, thermal, pasting, and moisture sorption properties of flours from chickpea, lentil, and yellow pea. *Food chemistry*, *295*, 579-587.
33. Farooqui, A. S., Syed, H. M., Talpade, N. N., Sontakke, M. D., & Ghatge, P. U. (2018). Influence of germination on chemical and nutritional properties of Barley flour. *Journal of Pharmacognosy and Phytochemistry*, *7*(2), 3855-3858.
34. Stowell, J. D. (2009). Polydextrose. In *Fiber ingredients* (pp. 187-218). CRC Press.
35. Cicek, B., Arslan, P., & Kelestimur, F. (2009). The effects of oligofructose and polydextrose on metabolic control parameters in type-2 diabetes. *Pak J Med Sci*, *25*(4), 573-8.

36. Samakradhamrongthai, R. S., Maneechot, S., Wangpankhajorn, P., Jannu, T., & Renaldi, G. (2022). Polydextrose and guar gum as a fat substitute in rice cookies and its physical, textural, and sensory properties. *Food Chemistry Advances*, *1*, 100058.
37. Ashwath Kumar, K., & Sudha, M. L. (2021). Effect of fat and sugar replacement on rheological, textural and nutritional characteristics of multigrain cookies. *Journal of Food Science and Technology*, *58*(7), 2630-2640.
38. Technology and laboratory practice of confectionery and food concentrates: teaching. manual / under the editorship Dorokhovych A. M., Kovbasy V. M. Kyiv: Inkos, 2015. 632 p.

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ПРАКТИЧНІ ПІДХОДИ ДО РЕГУЛЮВАННЯ ПОКАЗНИКІВ ЯКОСТІ ПІСОЧНО-ВИЇМНОГО ПЕЧИВА З ВИСОКИМ ВМІСТОМ НЕТРАДИЦІЙНОЇ СИРОВИНИ

Анотація

Здобне печиво відноситься до виробів, отриманих на основі в'язко-пластичного тіста, для якого характерна значна кількість жирових компонентів, цукру, застосування пшеничного борошна із середнім вмістом клейковини. Такий рецептурний склад робить готову продукцію висококалорійною, та, як правило, з низькою біологічною цінністю. У статті представлено результати дослідження, спрямовані на збагачення рецептурного складу здобного печива шляхом заміни пшеничного борошна на борошно амарантове та суміш пророщених злакових з одночасним регулюванням його цукровмісту введенням полідекстрози. На основі проведених теоретичних і експериментальних досліджень встановлено, що додавання амарантового борошна сприяє розвитку пружних деформацій в тісті і зменшує розвиток пластичних, призводить до розсипчастості, що пов'язано зі зменшенням вмісту клейковинних білків, неоднорідністю крохмальних зерен, у тому числі значним збільшенням амілопектинової фракції крохмалю. Максимально можливою є заміна 50 % пшеничного борошна на амарантове, яка не погіршує смак і аромат готової продукції, але надає як тісту, так і готовій продукції темних кольорів. Подальші заміни пшеничного борошна на подрібнену суміш пророщених злакових поглиблюють негативний вплив на структурно-механічні властивості тіста, а саме збільшується загальна деформація зразків, зменшується відносна пластичність та збільшується відносна пружність. Такі закономірності викликані внесенням значної кількості харчових волокон в суміші, а також низькомолекулярних водорозчинних з'єднань, накопичених завдяки гідролітичним процесам при пророщуванні. У готової продукції підвищується показник упікання, спостерігається збільшення розсипчастості. Експериментально підтверджено можливість внесення полідекстрози на заміну 50 % цукрової пудри для покращення структурно-механічних характеристик тіста на основі суміші амарантового борошна, суміші пророщених злакових і пшеничного борошна, але вплив на пластичні характеристики такої заміни несуттєвий. Для досягнення необхідних показників якості запропоновано введення ферментного препарату целюлолітичної дії Alhamalt HCF від виробника ТОВ «Штерн Інгредієнтс». Встановлено, що для консистенції тіста, яке піддавалось відлежуванню при температурі 35°С відбуваються суттєві зміни, воно набуває пластичності, необхідної для формування, не рветься, тістові заготовки не характеризуються деформацією швів, а готове печиво має гладку, не потріскану поверхню. У технологічну схему виробництва здобного пісочно-виїмного печива з високим вмістом нетрадиційної сировини запропоновано впровадити стадію відлежування тіста з підтриманням температури 35°С, яка дозволить протікання ферментативного гідролізу целюлози і її похідних під дією введеного ферментного препарату, збільшити накопичення водорозчинних цукрів, що призведе до пластифікації напівфабрикату.

Ключові слова: здобне печиво, амарантове борошно, полі декстроза, суміш пророщених злакових, структура тіста, пластичність, ферментні препарати.

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