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DETERMINING THE INFLUENCE OF VEGETABLE POWDERS ON THE FORMATION OF GINGER COOKIE QUALITY

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The object of this study is the technology of ginger cookies.

A serious issue is the spread of non-infectious diseases: obesity, diabetes, cancer, intestinal diseases, etc. This is caused by the consumption of "refined" foods, lack of dietary fiber and other nutrients in diets. Therefore, it is important to fortify flour confectionery products with sources of useful nutrients.

This paper has proven the effectiveness of using carrot powder to replace 10% of the total amount of flour and 4% of sugar and pumpkin powder to replace 15% and 6%, respectively, in the production of ginger cookies. Such solutions make it possible to fortify products with dietary fiber by 27.1% when adding carrot powder, and by 39.6% when using pumpkin powder. When using the latter, additional fortification with proteins occurs, by 23.1%. The addition of carrot powder helps reduce the glycemic index of ginger cookies by 5.1%, while the addition of pumpkin powder reduces this indicator within the margin of error.

It was found that the addition of carrot and pumpkin powders in the specified quantities increases the stretchability of gluten by 11.8% and 38.0%, respectively. At the same time, the elasticity decreases by 6.5% and 30.4%, respectively. Therefore, the fortified products are more fragile and have more developed porosity. Also, the devised ginger cookies have a darker color. This is explained by the significant content of β-carotene in vegetable powders: 10.2 mg/100 g and 18.5 mg/100 g, respectively. In addition, the powders contain a significant amount of simple sugars, which enhances the melanoidin formation reaction and positively affects the color of the products.

The results have practical significance for confectionery and craft manufacturers. The proposed technological solutions could make it possible to expand the range of ginger cookies with increased nutritional value and high quality indicators

Keywords: ginger cookies, carrot powder, pumpkin powder, nutritional value, dietary fiber

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1. Introduction

The global issue is the spread of food-borne diseases. They are mostly associated with malnutrition and an increase in the diet of "refined" foods. The economic and technical evolution of society also has negative consequences related to an increase in the number of chronic diseases. Among the diseases that progress along with the development of science and technology are obesity, diabetes, cancer, intestinal diseases, and other non-infectious diseases. All of the above leads to an increase in mortality worldwide [1]. This can be avoided by improving the nutritional profile of consumer products.

In [2] it was proven that daily consumption of foods rich in dietary fiber could reduce the risk of non-infectious diseases by 11%. The property of dietary fiber to prevent various diseases is associated with their physicochemical and adsorption characteristics. The high viscosity of dietary fiber and the ability to absorb glucose helps reduce the occurrence of diabetes. The ability to significantly swell and retain water, and to absorb cholesterol contributes to the fact that products fortified with dietary fiber have a lower calorie content. This is important for people with obesity and those who control their weight. The specified physicochemical properties of dietary fiber also improve intestinal peristalsis, and the adsorptive properties reduce the risk of cancer [3]. This can be explained by the ability of dietary fiber to absorb a significant amount of bile acids, other metabolites, toxins, and electrolytes [4].

It has been proven that the main products containing dietary fiber are fruits (16.7–91.4%), vegetables (6.5–85.2%), and cereals (9.8–69.2%) [3]. Such data indicate the feasibility of using plant raw materials in the technology of flour confectionery. It is this group of confectionery that attracts scientific interest since its production and consumption are approximately 30% higher compared to the sugar group [5]. Based on research data [3], promising fortification components are fruits, vegetables, and their processed products. It is advisable to consider ginger cookies as the object of fortification. Such a decision is relevant because it is this group of flour confectionery that is very popular among children and the elderly. That is, among those groups of people whose nutrition must be carefully controlled.

Ginger cookies are a unique flour confectionery product. Such products, unique within the group, have a spicy taste, which is achieved by using spices and seasonings in the recipe. However, ginger cookies, like all types of flour confectionery, have a number of issues. First of all, they relate to the use of high-grade flour, a significant amount of sugar and fat in the recipes. Due to this, the chemical composition of such products is rich in easily digestible carbohydrates. This is unacceptable for the nutrition of people with gastrointestinal diseases, obesity, and those who monitor their weight. In addition, a significant amount of sugar increases the glycemic index of the products. This can be a prerequisite for the occurrence of type II diabetes. In this regard, it is advisable to consider already known ways to improve the recipe composition of ginger cookies, giving them health-improving properties.

2. Literature review and problem statement

The range of flour confectionery products is mainly represented by butter, sugar, ginger cookies, gingerbread, cupcakes, muffins, etc. [6]. It should be noted that a significant number of works report finding ways to improve the recipe composition of butter cookies and giving them functional properties. Thus, in work [7], it is proposed to replace part of the margarine with sunflower oil. In order to improve the emulsifying ability, it is proposed to use pine and walnut meals. It was also established that cookies on a combined fat basis using pine and walnut meals have high quality indicators that are not lost during storage [8]. To improve the quality indicators of butter cookies, it is also advisable to use a composition of walnut and sesame meal to replace 20% of wheat flour [9].

The results of the studies in [10] indicate the feasibility of using buckwheat, rice, and corn flour in the production of sugar cookies. In [11], the feasibility of using sorghum, mung bean, and ground peanut flour in the production of shortbread cookies is substantiated.

All components proposed for enriching shortbread cookies in the above works are of grain or nut origin. This can be explained by the closeness of such non-traditional raw materials in composition and physical state to the main one – wheat flour. However, such solutions do not make it possible to fortify products with vitamins and minerals, which are more characteristic of fruit and vegetable raw materials. At the same time, the content of dietary fiber in it is higher compared to grain and nut raw materials [3].

It should be noted that most studies aim to fortify and improve the technology of shortbread cookies. However, ginger cookies are closer in characteristics to gingerbread products. Therefore, it is advisable to consider data on the fortification of gingerbread. Thus, in [12], a recipe and technology for the production of gluten-free gingerbread using sesame flour were devised. The developed technology allows for the production of gluten-free products with high organoleptic and physicochemical quality indicators.

It has also been proven that the use of pine and sesame flour, replacing part of the wheat flour, makes it possible to get high-quality products with increased nutritional and biological value. It is important that such a solution makes it possible to keep the freshness of finished gingerbread for a longer time without losing quality [13, 14].

In works [12–14], the prospects of using flour from grain and nut raw materials for obtaining gingerbread for health purposes have been proven. This is achieved by full or partial replacement of wheat flour in recipes. However, the issue of enriching gingerbread with dietary fiber and fat-soluble vitamins remains unresolved. The possibility of reducing sugar in the recipe has not been considered.

In order to reduce the glycemic index of shortbread cookies and give it health-improving properties, it is recommended to add 52.5% of sweet potato paste of the *Portu Beterraba* variety to the recipe. This achieves the goal of complete replacement of sugar and butter, as well as part of egg products in the recipe. It is claimed that such a solution is possible due to the significant content of sugars, protein, dietary fiber, and starch in sweet potatoes. In this case, butter cookies with health-improving properties, high quality indicators, increased nutritional and biological value are obtained [15].

There is also data on the replacement of 10% of powdered sugar in chocolate mass formulations with fruit and vegetable powders: pear, orange, pumpkin, beet. Such a solution makes it possible to obtain high-quality products from chocolate mass with a reduced glycemic index and increased nutritional and biological value. Fortification is achieved due to the rich chemical composition of the proposed powders [16].

The above data [15, 16] indicate the prospects for using plant raw materials to give confectionery products health-improving properties. However, no data were found on the use of sweet potato paste, pear, orange, and pumpkin powders to improve the nutritional profile of gingerbread products.

Considering the differences in the recipe composition and the course of technological operations in the production of butter and ginger cookies, which are mentioned above, it can be stated that the data reported in [15] will not be reliable for the range of flour confectionery products specified in the work. Also, the data given in [16] will not characterize the formation of the structure and quality of ginger cookies since they are described for the sugary group of confectionery products. Due to the fact that the rheological, physicochemical, and technological properties of gingerbread dough are unique, it was important to consider and study the influence of fruit and vegetable raw materials and products of its processing on the formation of the quality of finished products.

In order to fortify custard gingerbread with dietary fiber, in [17] it was proposed to replace 6% wheat flour with hemp protein. This makes it possible to obtain products with high nutritional and biological value. The use of hemp protein is a promising solution for enriching gingerbread since the additive has a composition similar in structure and physicochemical parameters to wheat flour. However, it should be noted that a slight replacement of the main high-calorie gluten-containing raw material will not significantly affect the health properties of the finished products. In addition, such a solution does not affect the glycemic index of gingerbread in any way since the sugar content in the recipe is not reduced.

In work [18], it is proposed to replace wheat flour with 5% chickpea and 10% bean flour. This solution makes it possible to fortify gingerbread with dietary fiber and vegetable protein, reduce its energy value. In the same work, a partial replacement of sugar with sugar beet powder is proposed to reduce the glycemic index of products. The resulting products are characterized by high quality indicators and nutritional and biological value. In addition, such gingerbreads have health-promoting properties due to the reduced gluten content and reduced glycemic index. The solutions reported in [17, 18] are scientifically and technologically significant, but do not solve the issue of enriching gingerbread with fat-soluble vitamins.

According to [19], it is advisable to replace 40% of the recipe amount of sugar with pumpkin puree. Such a solution helps increase the moisture content, swelling of raw gingerbread, and increases the shelf life. When implementing such a technological solution, the fortification of finished products with dietary fiber and fat-soluble vitamins is achieved. However, it should be emphasized that the use of fortification additives for flour confectionery in the form of puree has a number of technological difficulties.

Firstly, such raw materials spoil quickly. Therefore, they should be used in a short time after production – this complicates the process equipment, as it requires the installation of a fruit and vegetable processing line. Also, to extend the shelf life, such raw materials can be preserved. This may cause the presence of preservatives in the finished product, which will be negatively perceived by the consumer.

Secondly, it is necessary to more carefully control the introduction of fortifying raw materials. This is due to the fact that the structural indicators and physicochemical properties of the puree are significantly different from wheat flour. In addition, these indicators are not stable and may differ in different batches.

All of the above complicates the technological process and has a number of disadvantages. These problems can be solved by using raw vegetable materials in powdered form. However, the introduction of any non-traditional raw materials into the recipe of ginger cookies can not only positively affect their nutritional profile but also have an unpredictable effect on the formation of the quality of the finished product. Since much less work addresses the fortification of ginger cookies, it is advisable to study the influence of carrot and pumpkin powders on the formation of the quality of this group of confectionery products. Taking into account all of the above, a timely solution is to determine the influence of vegetable powders on the formation of the quality of ginger cookies.

3. The aim and objectives of the study

The purpose of our study is to determine the influence of carrot and pumpkin powder on the formation of the quality of ginger cookies. This will make it possible to expand the range of products from gingerbread dough for health purposes, will contribute to understanding the influence of vegetable powders on the formation of quality indicators of finished products.

To achieve the goal, the following tasks were formulated:

– to investigate the quality indicators and technological characteristics of carrot and pumpkin powder;

– to investigate the quality indicators and nutritional value of ginger cookies.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of our research is the technology of ginger cookies fortified with carrot or pumpkin powder. The hypothesis of the study assumes that the use of vegetable powders will make it possible to obtain high-quality ginger cookies with health-improving properties. This can be achieved by reducing the content of wheat flour and sugar in the product formulations.

It can be assumed that the rich chemical composition of carrot and pumpkin powders will contribute to the fortification of ginger cookies with dietary fiber, fat- and water-soluble vitamins, and minerals. It is expected that the replacement of part of wheat, rye flour, and sugar in ginger cookie formulations will affect the reduction of the glycemic index of finished products. However, it was not taken into account that the glycemic index of vegetable powders is higher than that of wheat and rye flour. This led to a non-significant decrease in this indicator only due to the reduction in the amount of sugar, which has a significantly higher glycemic index compared to the proposed powders.

4. 2. Methods to investigate quality indicators and technological characteristics of vegetable powders

For research and production of ginger cookies for health purposes, the main raw materials that met quality standards were used. Wheat flour of the 1st grade in accordance with GSTU 46.004-99. Peeled rye flour in accordance with DSTU 8791-2018. Sugar according to DSTU 4623-2023. Drinking water met the requirements of SanPiN 2.2.4-171-10 and DSTU 7525-2014. The work used butter, which in terms of quality indicators met DSTU 4399-2005. Table salt met the requirements of DSTU 3583-2015. Baking soda served as a baking powder in accordance with the requirements given in DSTU 2583-2020. The recipe included spices such as ginger, in accordance with DSTU ISO 1003:2005, and cinnamon according to the quality certificates provided by the manufacturer. Natural honey met the requirements of DSTU 4497-2005.

In order to give ginger cookies health-improving properties, the possibility of adding carrot powder (CP) or pumpkin powder (PP) by the Vestra Healthy brand (Ukraine) was considered. Vegetable powders met the manufacturer's quality certificates. According to the data, the method of low-temperature vacuum drying was used for the production of CP and PP. The temperature did not exceed 40°C. This solution makes it possible to preserve a significant amount of vitamins and minerals that will not be lost since the temperature does not rise above 50°C. It should be noted that the production of vegetable powders met the international standards DSTU ISO 9001, DSTU ISO 22000 (HACCP), DSTU ISO 14001.

When considering the possibility of using a particular non-traditional raw material to provide traditional products with health-promoting properties, it is important to understand what quality indicators the proposed raw material has. Therefore, at the first stage of research, quality indicators, technological characteristics, and other properties of carrot and pumpkin powders were investigated. Organoleptic indicators of wheat, rye, CP, and PP flour were determined by visual observation and tasting evaluation. Determination of acidity of wheat and rye flour was carried out in accordance with the methodologies given in the international standard ISO 7305:1998. Determination of moisture content in wheat and rye flour was carried out in accordance with ISO 712-1:2024. Titrated acidity and moisture of vegetable powders were investigated in accordance with standard methodologies used for fruit and vegetable raw materials and products of their processing [20].

Since the fortification of ginger cookies with dietary fibers is promising, it is advisable to determine their amount in CP and PP. The fiber content in vegetable powders, wheat and rye flour was determined by the modified Scharrer method and ISO 6541:1981, the amount of pectin substances – by the methodology given in [21]. The cellulose and hemicellulose content in the basic and fortifying raw materials was determined by the method using sulfuric acid according to ISO 1833-11:2017.

In addition to dietary fibers, sufficient vitamin intake is important for the human body. In addition, some vitamins, along with their functional value for the human body, also have technological characteristics that enhance the antioxidant properties of the product. This can also have a positive effect on the shelf life of products rich in vitamins. In this regard, it was decided to determine the content of vitamins C and β-carotene in vegetable powders. The content of vitamin C in vegetable powders was determined using the indophenol method [22], and β-carotene – according to ISO 6558-2:1992.

Given the significant prevalence of obesity and diabetes in humans, it is important to reduce the energy value and glycemic index of ginger cookies. To understand how much the sugar content in the recipe can be reduced, it is important to study the content of sugars and their qualitative composition in the fortifying raw materials. The quantitative and qualitative composition of sugars in CP and PP was determined by the Schorl method according to the methodology given in [23].

To carry out the technological process and obtain high-quality products, it is important to understand the technological characteristics of the fortifying raw materials and their impact on the main raw materials. Therefore, at the next stage of research, the impact of carrot and pumpkin powder on the quantity and quality of wheat flour gluten was studied according to ISO 21415-2:2015.

4. 3. Methods for studying the quality and nutritional value of ginger cookies

To determine the effect of carrot and pumpkin powders on the quality and nutritional value of ginger cookies, batches of products were manufactured under laboratory conditions according to the recipes given in Table 1.

Table 1

Gingerbread cookie recipes using carrot or pumpkin powder

Raw material ID	Amount of raw materials, kg, per 1 ton of finished product				
	Control, kg	With the addition of carrot or pumpkin powder			
		Sample 1, Sample 2	Sample 3, Sample 4	Sample 5, Sample 6	Sample 7, Sample 8
Wheat flour, grade 1	340.00	323.00	306.00	289.00	272.00
Scrubbed rye flour	220.00	209.00	198.00	187.00	176.00
Carrot or pumpkin powder	–	32.00	64.00	96.00	128.00
Honey	200.00	200.00	200.00	200.00	200.00
White granulated sugar	200.00	196.00	192.00	188.00	184.00
Mélange	66.00	66.00	66.00	66.00	66.00
Butter	12.00	12.00	12.00	12.00	12.00
Baking soda	1.60	1.60	1.60	1.60	1.60
Table salt	0.05	0.05	0.05	0.05	0.05
Ground ginger	0.08	0.08	0.08	0.08	0.08
Ground cinnamon	0.02	0.02	0.02	0.02	0.02
Ground nutmeg	0.02	0.02	0.02	0.02	0.02
Ground cardamom	0.02	0.02	0.02	0.02	0.02
Ground cloves	0.01	0.01	0.01	0.01	0.01
Total	1039.80	1039.80	1039.80	1039.80	1039.80

Sample 1 – ginger cookies with the addition of 5% CP to replace flour and 2% CP to replace sugar.

Sample 2 – ginger cookies with the addition of 5% PP to replace flour and 2% PP to replace sugar.

Sample 3 – ginger cookies with the addition of 10% CP to replace flour and 4% CP to replace sugar.

Sample 4 – ginger cookies with the addition of 10% PP to replace flour and 4% PP to replace sugar.

Sample 5 – ginger cookies with the addition of 15% CP to replace flour and 6% CP to replace sugar.

Sample 6 – ginger cookies with the addition of 15% PP to replace flour and 6% PP to replace sugar.

Sample 7 – ginger cookies with the addition of 20% CP to replace flour and 8% CP to replace sugar.

Sample 8 – ginger cookies with the addition of 20% PP to replace flour and 8% PP to replace sugar.

All raw materials used for the production of ginger cookies are pre-prepared, cleaned of impurities. The butter is softened and whipped to form a lush plastic mass for 10 minutes.

We then add the prepared ingredients: sugar, salt, baking powder, egg white to the whipped butter. We beat until smooth. Then gradually, in small portions, we add the premixed wheat, rye flour, and spices. When producing test samples (Table 1), it is recommended to add the calculated amount of CP or PP together with the flour during dough mixing. In order to obtain control and test samples of ginger cookies, the dough should be kneaded to plastic consistency. After that, we cool it for 30–60 minutes to a temperature of 5–7°C, form the products, and bake at a temperature of 200°C for 10–12 minutes. It should be noted that the control and experimental samples of gingerbread were baked without decoration. This decision was made in order to objectively determine the effect of vegetable powders on the quality indicators of the resulting products.

In baked gingerbread, alkalinity, moisture, wettability, and crumbliness were determined according to the methodologies given in [23].

The organoleptic assessment of the finished products was carried out on a 5-point scale by tasting and in accordance with the requirements of DSTU 4683:2006.

All quality indicators of the finished products were determined 24 hours after baking.

Taking into account the rich chemical composition of CP and PP and the fact that they replaced part of the wheat, rye flour, and sugar, the nutritional value and glycemic index of the products were calculated according to the methodology described in [24].

Table 2

Quality indicators of basic and fortifying raw materials ($n = 5$, $P \geq 0.95$, $\sigma = 3–5\%$)

Quality indicator	Indicator value			
	Wheat flour	Rye flour	Carrot powder	Pumpkin Powder
Appearance	Dry powdered product			
Color	White with a grayish tint	Grey	Cream with an orange tint	Golden orange
Taste	No off-flavors, no bitter, no sour, no crunch		Sweet and sour, with a carrot flavor	Sweet, with a vegetable flavor
Smell	Characteristic of the variety, no extraneous, not musty, not moldy		Characteristic of carrots	Characteristic of pumpkin
Acidity, degrees	3,1	4,7	6,1	5,9
Humidity, %	14,3	14,0	11,8	12,4

4. 4. Statistical treatment of research results

The error for all studies was $\sigma = 3–5\%$, the number of parallel experiments – $n = 5$, the probability – $P \geq 0.95$. Experimental data were processed statistically using the Fisher-Student method at a reliability level of 0.95. The results were calculated as the arithmetic mean of at least five experiments. The MS Office 2016 application package, including MS Excel (USA), was used to treat experimental data.

5. Results of determining the quality indicators of vegetable powders and ginger cookies for their use

5. 1. Results of studying the quality indicators and technological characteristics of vegetable powders

In the process of developing confectionery recipes with the addition of non-traditional raw materials, it is advisable to analyze its organoleptic properties. This is due to the fact that the added additive can have a potential impact on the sensory characteristics of the finished product, in particular the taste and aroma profile and consistency of ginger cookies. These indicators not only determine the perception of the finished product by the consumer but also affect the efficiency of the technological process. It is the physicochemical parameters that largely determine the quality of ginger cookies as a whole. Therefore, at the first stage of research, organoleptic and physicochemical indicators of carrot and pumpkin powders that will be used in technology were studied. A comparison was made with the main raw materials: wheat and rye flour (Table 2).

According to the organoleptic evaluation data (Table 2), all raw materials met the requirements of the quality standards specified in chapter 4. There were no foreign flavors and odors.

It should be noted that the acidity of carrot powder is higher compared to wheat flour by 96.8%, rye flour by 29.8%, and pumpkin acidity by 90.3% and 25.5%, respectively. This will significantly affect the formation of the taste and aroma profile of finished products since during temperature treatment, acids are not neutralized.

The moisture content of vegetable powders, on the contrary, is lower compared to wheat and rye flour: in CP – by 21.2% and 18.6%, respectively, in PP – by 15.3% and 12.9%, respectively. This may have a technological effect, affecting the baking modes of ginger cookies using vegetable powders.

The content of dietary fiber in the fortifying raw materials will not only have a positive effect on the nutritional profile of ginger cookies but will also affect the quality of finished products. Therefore, it is important to determine the amount of these polysaccharides in CP and PP (Table 3).

Vitamins C and β-carotene are important for the human body. Given the presence of these vitamins in vegetable powders, it can be argued that they exhibit antioxidant properties (Table 3).

Table 3

Content of dietary fiber and vitamins in carrot powders and ($n = 5$, $P \geq 0.95$, $\sigma = 3–5\%$)

Indicator	The value of the indicator in raw materials	
	CP	PP
Dietary fiber, g/100 g, including: Fiber	5.1	3.9
Pectin substances	0.9	7.1
Cellulose	19.2	10.8
Hemicellulose	19.0	24.3
Vitamins, mg/100 g, including: C	90.0	6.6
β-carotene	10.2	18.5

According to the data given in Table 3, vegetable powders are:

– characterized by a high content of dietary fiber. Along with the significant content of vitamin C and β-carotene, this may also indicate a possible increase in the antioxidant status of ginger cookies.

When designing health food products with a reduced glycemic index, along with the content of dietary fiber and vitamins, we must take into account the composition of sugars in the fortifying raw materials (Table 4).

Table 4

Qualitative composition of sugars in vegetable powders ($n = 5$, $P \geq 0.95$, $\sigma = 3–5\%$)

Sugar	Content in the studied raw materials, %	
	CP	PP
Glucose	25.0	28.2
Fructose	32.4	31.7
Sucrose	18.7	21.4
Maltose	23.9	18.7
Total sugar	7.6	9.0

The data given in Table 4 indicate that PP is characterized by an 18.4% higher content of total sugar. PP, compared to CP, also contains more glucose and sucrose, by 12.8% and 14.4%, respectively. This will affect both the formation of organoleptic indicators of ginger cookies and its glycemic index (GI). Also, the specified qualitative composition of sugars in vegetable powders confirms the possibility of replacing the proportion of sugar in the recipe. It should be noted that it is important to study the influence of fortifying raw materials on the quality indicators of wheat flour. The quality of finished products largely depends on this. Therefore, at the next stage of research, the influence of carrot and pumpkin powder on the quantity and quality of gluten was studied (Table 5).

Table 5

Effect of vegetable powders on gluten properties of wheat flour ($n = 5$, $P \geq 0.95$, $\sigma = 3–5\%$)

Gluten sample	Gluten quality indicators			
	Amount of raw, %	Stretchability, cm	Elasticity on the IDK device, units	Color
Without additives (control)	25.1	15.0	75.0	Cream
With CP addition, % of flour mass: 5	22.5	15.5	78.7	Gray
10	22.2	17.0	80.2	Gray-yellow
15	20.4	18.7	83.7	Yellow-gray
20	19.4	20.0	87.3	Orange-gray
With the addition of PP, % of the weight of flour: 5	24.0	20.0	102.5	Cream-yellow
10	21.4	22.3	103.2	Gray-yellow
15	19.6	24.2	107.7	Yellow
20	15.1	26.4	110.1	Yellow-orange

It was found that the introduction of carrot and pumpkin powders causes a decrease in the yield of raw gluten and weakens it. That is, the introduction of vegetable powders will significantly affect the formation of the quality of ginger cookies.

Considering the chemical composition of CP and PP, which is different from the main raw materials, as well as their influence on the technological characteristics of flour, it is advisable to study the quality indicators of ginger cookies, their nutritional value, and GI.

5. 2. Research on the quality indicators and nutritional value of ginger cookies fortified with vegetable powders

Considering the chemical composition of vegetable powders (Tables 3, 4) and their technological characteristics (Tables 2, 5), the quality indicators of finished products with the introduction of enriching raw materials were studied. The results are given in Table 6.

Table 6

Physical-chemical and structural-mechanical quality indicators of ginger cookies fortified with vegetable powders ($n = 5$, $P \geq 0.95$, $\sigma = 3–5\%$)

Sample of ginger cookies	Indicator and its value			
	Alkalinity, degree	Humidity, %	Wettability, %	Crumbliness, cm
Control (no additives)	2.0	15.0	162.9	3.0
With the introduction of CP, % of the total mass of flour				
5	2.0	15.6	234.1	2.7
10	1.8	16.4	220.5	2.5
15	1.5	17.1	195.7	2.3
20	1.3	17.9	170.8	2.1
With the introduction of PP, % of the total mass of flour				
5	2.0	15.4	202.5	3.2
10	2.0	15.9	208.8	3.8
15	1.5	16.5	215.4	4.1
20	1.2	17.1	226.3	4.9

According to our data (Table 6), ginger cookies fortified with carrot and pumpkin powders have a higher moisture content by 3.8–16.2% and 2.6–12.3%, respectively, compared to the control sample. However, vegetable powders had different effects on the crumbliness of ginger cookies. Thus, with the addition of CP, this indicator decreased with an increase in the amount of powder in the system by 11.1–42.9%, and with the addition of PP, on the contrary, it increased by 6.3–38.8%.

According to organoleptic indicators, ginger cookies with the addition of CP and PP met the standards for the specified products. The color of ginger cookies with the addition of CP acquired a yellowish tint, which intensified with an increase in the amount of powder in the system. The aroma of ginger cookies was spicy, corresponding to the product group. The products were characterized by a light carrot aroma and carrot flavor, which intensified with an increase in the amount of powder. It should also be noted that with an increase in CP in the recipe, the structure of the products became undeveloped, lingering.

The color of ginger cookies with the use of PP acquired a golden-brown hue that intensified with an increase in the powder in the system. The aroma of ginger cookies was spicy, corresponding to the group of products. The products were characterized by a pleasant, sweet taste without foreign flavors. Pumpkin tones were absent in the aroma and taste. The structure of ginger cookies with the introduction of PP became more developed, crumbly. The surface of the products had characteristic cracks.

When designing health-improving products, it is important to assess their nutritional value. The results of the influence of vegetable powders on the nutritional value of ginger cookies are shown in Fig. 1.

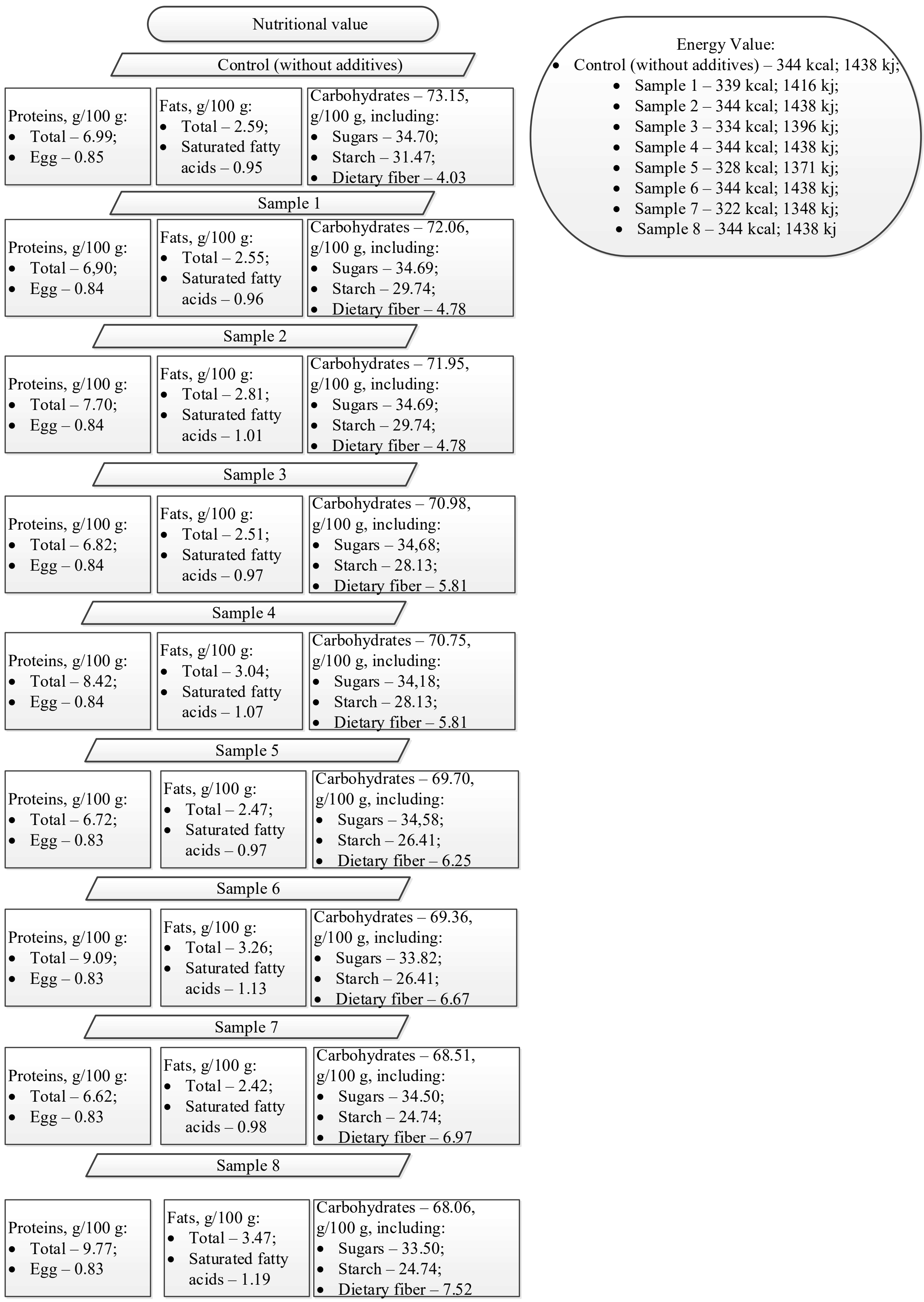

Fig. 1. Nutritional and energy value of ginger cookies fortified with vegetable powders

According to our data (Fig. 1), ginger cookies with the addition of PP increased the protein content by 10.2–39.8% compared to the control. The content of dietary fiber increased by 20.7–86.6% but the energy value of such products remained unchanged. At the same time, the addition of CP causes a slight decrease in the protein content in finished products. However, it contributes to an increase in the content of dietary fiber by 18.6–72.9%. At the same time, the addition of carrot powder contributes to a slight decrease in the energy value of ginger cookies.

Along with the nutritional value, the glycemic index is important for ginger cookies with functional properties (Fig. 2).

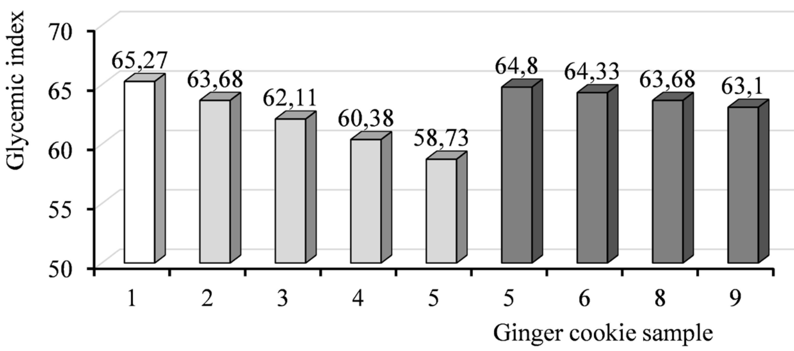

Fig. 2. Effect of carrot and pumpkin powders on the glycemic index of ginger cookies: 1 – control (without additives); with the addition of carrot powder: 2 – sample 1; 3 – sample 3; 4 – sample 5; 5 – sample 7; with the addition of pumpkin powder; 6 – sample 2; 7 – sample 4; 8 – sample 6; 9 – sample 8

It was found that the introduction of CP in a minimum amount (5% of the total mass of flour and 2% of the mass of sugar) affects the reduction of GI within the error range. Increasing the amount of this powder in the recipe contributes to a decrease in this indicator by 5.1–11.1%.

Characterizing the effect of PP on the glycemic index of finished products, it can be stated that it does not have a significant effect since it decreases within the error range.

Thus, it was found that the introduction of carrot and pumpkin powders into ginger cookies recipes would positively affect the nutritional value of finished products. The content of dietary fiber and protein increases (with the introduction of PP). This could have a positive effect on the nutritional profile of the specified flour confectionery products. However, such solutions do not contribute to a significant reduction in the glycemic index of ginger cookies.

6. Discussion of results of studies on the influence of vegetable powders on the quality of ginger cookies

It was found that the proposed vegetable powders differ in color from wheat and rye flour (Table 2). This is due to the significant content of carotenoids in them, namely β-carotene. In CP, this vitamin is contained in an amount of 10.2 mg/100 g, and in PP – 18.5 mg/100 g (Table 3). This composition of the powders causes a change in the color of ginger cookies, giving them shades from golden to dark brown. That is, using natural raw materials, it is possible to change the color of finished products, which was confirmed in [25]. However, in [25] it is stated that the color change of shortbread cookies occurs due to the interaction of grape powder polyphenols with wheat flour proteins. However, the processes occurring in shortbread cookies can only indirectly characterize the formation of the color of ginger cookies. It should be noted that the additives proposed in [25] are close to those considered in the present work and therefore may have a similar effect on related dough systems. However, this can only partially characterize the color change of the experimental products since the significant content of carotenoids in carrot and pumpkin powders should be taken into account.

In [26], the possibility of using pumpkin pomace as dyes that can be used in the food industry was proven. This possibility is explained by the significant content of β-carotene in pumpkin pomace. These data correlate with the data obtained in the course of our studies on the change in the color of ginger cookies using PP. However, in [26], a specific technology is not singled out in which the dye from pumpkin pomace would be used. In addition, obtaining products of a darker color is possible due to the significant content of simple sugars in vegetable powders (Table 4), which would enhance the melanoidin formation reaction during baking. This correlates with the data reported in [25, 26], which confirm the possibility of using natural components as dyes. Thus, due to the complex action of β-carotene (Table 3) and simple sugars (Table 4) in vegetable powders, a significant change in the color of finished products can be explained.

Simple sugars, along with the effect on the color of the products, have a positive effect on the change in the GI of ginger cookies, reducing it (Fig. 2). Especially so when using carrot powder in an amount of 10–20% of the total mass of flour and 4–8% of the mass of sugar. At the same time, the GI of finished products is reduced by 5.1–11.1%. This is a positive factor that was not taken into account in work [19].

In addition to the color of the products, their taste and aroma significantly affect consumer properties. Considering the higher, compared to flour, acidity of CP and PP, which is 6.1 degrees and 5.9 degrees, respectively (Table 2), the taste of the products changed. This is due to the fact that acids are not destroyed during baking and affect the formation of the taste of ginger cookies, giving it special shades.

Ascorbic acid, which is found in significant amounts in vegetable powders (Table 3), can also influence the formation of taste. In addition to affecting the taste of products, vitamin C can act as an antioxidant. This will give finished products antioxidant properties, extend their shelf life, and also have an immunostimulating effect.

It should be noted that products with CP had carrot notes in the aroma, while pumpkin notes were absent in products with PP. This may be due to the different origin and composition of aromatic substances and organic acids in the fortifying raw materials.

The content of dietary fiber in the fortifying raw materials is of great importance for the creation of health-promoting products. It is dietary fiber that contributes to faster satiety, which prevents overeating. These nutrients also stimulate intestinal motility, remove radio nuclides, toxins, etc. from the human body [27]. Unlike frozen Moti desserts, which are discussed in [27], ginger cookies are consumed by a larger part of the population. This indicates that it is very important to improve the technology of its production in such a way as to provide more people with useful products. Using vegetable powders in the ginger cookie recipe, we obtain products with a dietary fiber content that exceeds the similar value in the control sample. When using CP, the dietary fiber content increases by 18.6–72.9%, and when adding PP – by 20.7–86.6% (Fig. 1). This result was achieved due to the significant content of this nutrient in the proposed powders (Table 3).

The use of PP in the recipe of ginger cookies makes it possible to additionally fortify the finished products with protein (Fig. 1). Thus, the protein content in ginger cookies increases by 10.2–39.8% compared to the control. This is probably due to the significant amount of this component in pumpkin [26].

The advantage of using carrots and pumpkin as a fortifying additive in powdered form is that such a solution greatly simplifies the technological process and production control. Unlike pumpkin puree [19], the powders are close in structure to flour, which simplifies their introduction. The fortifying additive in dry form is more resistant to microbiological spoilage. This will significantly increase the safety of production.

According to the results of our work, it is recommended to use carrot powder in an amount of 10% of the total mass of flour and 4% of the mass of sugar. Considering the possibility of using pumpkin powder, it was found that it is advisable to add it in an amount of 15% of the total mass of flour and 6% of the mass of sugar. Such decisions were made because a smaller amount of powders does not significantly affect the nutritional value and GI of products (Fig. 1, 2). The introduction of vegetable powders in larger quantities causes a decrease in the quality indicators of ginger cookies (Table 6). This is especially noticeable when using CP. Products with its introduction, with increasing dosage, have less developed porosity, become harder. This can be explained by the insignificant effect of CP on wheat flour gluten (Table 5) and, at the same time, a high content of dietary fiber (Table 3).

The addition of PP significantly reduces the quality of wheat flour gluten (Table 5). Thus, the stretchability increases by 25.0–43.2%, elasticity decreases by 26.8–31.9% compared to the sample without the introduction of experimental powders. According to our results (Table 5), gluten with the use of PP can be attributed to the III quality class "unsatisfactorily weak". In this case, even a significant influence of dietary fibers in pumpkin powder (Table 3) will not strengthen the dough structure.

It should be noted that in the production of ginger cookies, the weakening of wheat flour gluten has a positive effect on the quality of finished products. The dough for such products should be loose, plastic-viscous. This is the result that can be achieved with the introduction of PP. This was confirmed experimentally (Table 6). The increase in the wettability index of ginger cookies by 19.6–28.0% with the introduction of the specified powder indicates a more developed porosity of the experimental samples. The friability index also increases by 6.3–38.8%, which is positive for this group of products. However, friability with the introduction of the maximum amount of PP (20% of the total mass of flour and 8% of the mass of sugar) causes the formation of too brittle products. This can increase the number of defective products at the enterprise. Therefore, the use of pumpkin powder in the maximum dosage is not a promising solution.

Unlike PP, the smallest amount of CP contributes to the highest wettability value, which increases by 30.4% compared to the control. However, an increase in the dosage of the specified powder causes a decrease in this indicator compared to a smaller amount of additive in the system. However, such values are still higher compared to the control by 27.1–4.6%. The crumbliness of such products is reduced by 11.1–42.9% compared to the control sample. Such data confirm the assumption that the slight weakening of gluten due to the introduction of CP is offset by the significant content of dietary fiber in it and is not positive for the technology of ginger cookies.

When implementing our results industrially, the technology and recipes described should be strictly adhered to. It should also be taken into account that deviations from our results are possible when using carrot and pumpkin powders from other manufacturers. This is due to possible differences in the technological process of powder production at different enterprises.

The disadvantages of this study include the fact that the structural and mechanical properties of dough systems were not considered and the need to change the technological parameters of baking ginger cookies was not taken into account. This may lead to the fact that the experimental products could be overbaked or underbaked. However, this decision was made deliberately in order to assess the impact of standard baking parameters on samples of ginger cookies fortified with vegetable powders. The results were described, and ways of further research were formulated.

Taking into account the above, further research will be aimed at studying and establishing the necessary technological parameters for obtaining high-quality products. It is also planned to investigate the antioxidant properties of CP and PP and the effect of these powders on the storage of ginger cookies. This will make it possible to adjust the technological process of the developed products, predict the terms of their preservation of freshness, and expand the assortment of the group of these flour confectionery products.

7. Conclusions

1. We have established that all the raw materials proposed for the production of ginger cookies met the established requirements. It should be noted that the orange shades in carrot and pumpkin powders are due to the significant content of β-carotene in them – 10.2 mg/100 g and 18.5 mg/100 g, respectively.

The use of vegetable powders makes it possible to improve the nutritional profile of ginger cookies by enriching them with dietary fiber. It was established that carrot powder contains, g/100 g: fiber – 5.1; pectin substances – 0.9%; cellulose – 19.2; hemicellulose – 19.0. In pumpkin powder, the amount of the listed dietary fiber is 3.9 mg/100 g; 7.1 mg/100 g; 10.8 mg/100 g; 24.3 mg/100 g, respectively. In addition, the content of vitamin C in carrot and pumpkin powder has a positive effect on the nutritional profile of the products: 90.0 mg/100 g and 6.6 mg/100 g, respectively.

It has been experimentally proven that the addition of carrot or pumpkin powder causes a weakening of the gluten of wheat flour. Thus, when using the first powder in the recipe, the stretchability of gluten increases by 3.2–25.0%, while elasticity, on the contrary, decreases by 4.7–14.1%. When using the second, the stretchability increases by 25.0–43.2%, and elasticity decreases by 26.8–31.9% compared to the sample without the addition of vegetable powders. The change in the color of gluten when using both powders confirms the effect of β-carotene as a dye, which can affect the color change of finished products.

2. It has been proven that ginger cookies with the addition of vegetable powders acquire darker shades compared to the control sample. This confirms the effect of β-carotene as a dye. Also, the color change of finished products is influenced by a significant amount of simple sugars in the composition of vegetable powders. Thus, carrot powder contains, %: glucose – 25.0; fructose – 32.4; sucrose – 18.7; maltose – 23.9; total sugar – 7.6. In pumpkin powder, the percentage of the listed sugars is as follows – 28.2%; 31.7%; 21.4%; 18.7%; 9.0%, respectively. Such a composition of sugars enhances the melanoidin formation reaction and has a positive effect on the color of finished products, giving them darker shades.

It was found that the use of carrot and pumpkin powders differently affects the quality of ginger cookies. However, in both cases, the introduction of powders makes it possible to obtain products with a significant content of dietary fiber. Thus, with the introduction of carrot powder, the amount of dietary fiber in finished products increases by 18.6–72.9%, with the introduction of pumpkin powder – by 20.7–86.6%. With the use of the latter, the protein content in ginger cookies also increases by 10.2–39.8%. The use of carrot powder in a minimum amount and pumpkin powder in the entire dosage range reduces the glycemic index of finished products within the error range. However, increasing the amount of carrot powder in the recipe makes it possible to reduce this indicator by 5.1–11.1% compared to the control.

Considering all of the above, it is recommended to use carrot powder in an amount of 10% of the total mass of flour and 4% of the mass of sugar to give ginger cookies health-promoting properties. It is recommended to use pumpkin powder, replacing 15% of the total mass of flour and 6% of the mass of sugar. Such solutions make it possible to obtain products with high quality indicators and increased nutritional value.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

All data are available, either in numerical or graphical form, in the main text of the manuscript.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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