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The effect of adding carrot or beetroot powders on the quality indicators of round cracknel products

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Abstract. The relationship between carrot/beetroot powders added, the quantity and quality of gluten in the flour and the moisture, acidity, swelling coefficient and the quality indicators of round cracknel products has been studied. The carrot and beetroot powders, produced by Vitbiokor, LLC, and the premium wheat flour were used. The powders were introduced in a dry and hydrated form. The hydration was carried out at the hydromodule of 1:5 for 40 minutes. The particle size analysis of raw materials was conducted with the laser diffraction analyzer Malvern Mastersizer 2000. The proportion of particles of less than 200 μm in the flour made 100%, in the carrot powder - 77%, in the beetroot powder - 71%. The introduction of carrot/beetroot powders in the amount of 1.5%, 3.0%, 6.0% and 9.0% by weight of the flour reduces the amount of gluten. Still, it strengthens the latter, making it possible to mold products with developed porosity. The introduction of dry carrot powder in the amount of 6% into the sourdough and the dough (1.5%, 3.0%, 6.0% and 9.0%) increases the swelling coefficient of the end products by an average of 15%, while the introduction of the hydrated powder does it by 40%. Similarly, the introduction of the dry beetroot powder leads, on average, to a 12% increase and of the hydrated powder to a 22% increase. The obtained results proved the effectiveness of introducing carrot/beetroot powders (preference given to their hydrated types) into the recipe of round cracknel products.

Key words: round cracknel products, carrot and beetroot powders, the quantity and quality of gluten, swelling coefficient.

INTRODUCTION

The consumption of functional and healthy food is growing in a modern person's diet (Mollakhalili-Meybodi et al., 2021; Amani & Aljahani, 2022). Due to the ability to benefit human health, there has recently been an increase in functional foods production. Functional foods are foods fortified with compounds providing additional health and safety benefits, e.g. vitamins, minerals, and bioactive compounds (Balakrishnaraja et al., 2021; Zarzycki et al., 2022). A high amount of the required components is contained in the vegetable powders. Therefore, such mass consumption foods as bakery products are enriched (Gryazyina et al., 2016; Nevskaya et al., 2020).

Among the range of goods produced by the baking industry, a special place is occupied by round cracknel products. Round cracknel products belong to the low humidity products with a moisture content of no more than 19% (GOST 32124, 2013). They are products with a longer shelf life (25 or more days) than bread (3–5 days), making them very attractive for consumers. Moreover, the round cracknel products retain their original properties throughout the entire shelf life.

The important indicator of the round cracknels' quality is their swelling coefficient. The swelling coefficient, i.e. hydrophilicity of bagels is the ability to swell and soften in warm water without destroying the structure. To make this happen, water must penetrate as much as possible through the crust of the product, fill the internal space and be retained in it. Therefore, the appropriate product structure must be created: a sufficiently large number of pores with thin, but at the same time strong walls, evenly distributed over the entire inner surface of the product (Shirokova & Veselova, 2016).

The formation of the product structure occurs during the dough preparation process. It involves the following ingredients: flour (which contains natural high-molecular compounds with a large number of functional groups), yeast-microorganisms (which are natural leavening agents of the dough emitting carbon dioxide, which forms the porous structure of the product), and water (which dissolves high-molecular flour compounds and participates in complex physico-chemical and colloidal processes when making bakery products).

At the initial stage of the dough preparation, it is necessary to arrange the homogeneity of the mass. Its formation depends on the dispersion degree of the ingredients added to the flour. The difference between the particle size of the ingredient and the degree of flour dispersion should be as minor as possible (Karama et al., 2016; Taniguchi et al., 2022). When mixing the dough, it is important to wet the flour and the ingredients included in its composition, i.e. vegetable powders. To increase the water absorption properties of the flour, vegetable powders should have good moisture binding capacity (Rudnev et al., 2021).

During the dough preparation, the interaction of flour components (carbohydrates and proteins) with water forms the gluten quality. For the round cracknels production, flour with strong gluten is needed.

The sourdough is also involved in the formation of the qualitative properties of gluten. Its quantity regulates the strength of gluten (Akhmetzhanova & Savkina, 2017).

If the flour with poor gluten is used, the amount of sourdough added should be increased. The yeast used in the preparation should have a high fermentation activity, i.e. release as much carbon dioxide as possible with less flour added. The vegetable powder components contain the necessary nutrients stimulating the yeast biochemical system.

The speed of the fermentation process at these stages depends on the readiness of the powder components for the interaction with the yeast, i.e., the degree of solubility or the ability to dissolve quickly. It is possible to increase the degree of solubility of these components by the pretreatment of the powders, such as hydration. Hydration provides the process of swelling of the powder components. Water penetrates the high-molecular components of plant materials while maintaining powder integrity. A part of the water molecule binds by absorption to macromolecular substances of the powder while a part of the molecules penetrates the internal structure of the swelling substance due to diffusion (Douglass & Harrowell, 2018; Drake et al., 2018). As a result, there is a significant increase in the powder volume.

As a result, some of the low-molecular components of the swelling substance can go into a dissolved state, affecting the process of powder components penetration into the yeast cell and the entire fermentation process (Allert & Adshevskaya, 2017; Koryachkina et al., 2018).

Osmotically bounded water is water bound with ions, which forms hydration shells around the charged particles and water associated with the well-dissolved low molecular weight compounds (Murashov, 2013). After interacting with the osmotic water, the end round cracknels must not fall apart. This requirement is ensured by the state of the colloidal system and the quality of flour gluten: it should be elastic but strong enough.

One more important indicator of the bakery products' quality is acidity because it shows the readiness of the fermented semi-finished product, i.e. sourdough or dough. The dough is loosened with carbon dioxide. During the fermentation period, there is an accumulation of products determining the taste and aroma of bakery products made from the well-fermented dough.

The previous studies have shown that the formed organic acids or the additionally introduced ones contribute to the swelling of gluten proteins, affecting the physical and colloidal properties of the dough (Gatko, 2004).

Promising vegetable raw materials with several advantages are dry carrot and beetroot powders (Hobbs et al., 2014; Zubkova & Zakharov, 2016). The advantage of these powders is that they are made from the vegetables that are widely grown in all regions of the world, relatively cheap, rich in vitamins C, B1, B2, B5, B6, PP, E, folic acid, provitamin A, and also include a high content of colouring substances, e.g. betaine, betanin, beta-carotene (Dombrovskaya et al., 2017; Kapoor & Feng 2022).

This study aims to investigate the effect of carrot and beetroot powders on the quality of gluten, evaluate the prospects of carrying out carrot and beetroot powders hydration, and estimate their effect on the swelling acidity of round cracknels.

MATERIALS AND METHODS

The dry carrot and beetroot powders produced by Vitbiokor, LLC (the Republic of Belarus) were used for the experiment. The chemical composition is presented in Table 1 (Godunov, 2021).

Moreover, the following ingredients were used: premium wheat flour *Predportovaya* (Saint Petersburg Mill Plant, JSC), pressed bakery yeast (Combinat Food Products, JSC), refined deodorized sunflower oil (MEZYugRusi, LLC), common salt (Araltuz, JSC), and granulated sugar (Prodimeks, LLC).

Table 1. The chemical composition of raw materials

Nutrient	Sample name	
	Carrot powder	Beetroot powder
Protein, %	10.0	9.9
Fats, %	0.8	0.7
Carbohydrates, %	55.2	59.8

The particle size distribution of raw materials has been analyzed with the help of the laser diffraction analyzer *Malvern Mastersizer 2000*.

The amount of gluten in flour was determined according to GOST 27839-2013 standard. The raw gluten was extracted from the dough produced with pure wheat to flour and from that made of wheat flour with carrot and beetroot powders added in the ratio of 1.5%, 3.0%, 6.0%, 9.0% by weight of flour and water (Table 2).

Table 2. Dough recipe for calculating the amount of gluten

Raw material	Sample type				
	Control sample	1.5%	3.0%	6.0%	9.0%
Premium wheat flour, g	30.00	29.55	29.1	28.20	27.30
Drinking water, g	17.00	17.05	17.08	17.16	17.25
Dry carrot/beetroot powder, g	0	0.45	0.90	1.80	2.70
TOTAL, g	47.00	47.05	47.08	47.16	47.25

The prepared dough samples were washed with the gluten washing machine (*U1-MOK-1MT)*. Water-soluble substances, as well as starch and bran, were removed from the dough. The raw gluten washed out was weighed and calculated as a proportion of the total mass of the sample analyzed.

The quality of gluten was determined with the gluten deformation measuring device (*IDK-3M*). To determine the value of resistance to compressive load deformation, the raw gluten was formed into a ball of 120 g. The measuring process took 30 seconds.

For preparing the round cracknel products, the sponge-and-dough method was used. The sourdough recipe is shown in Table 3. The amount of dry or hydrated carrot or beetroot powder introduced made up 6% of the flour weight based on previous research findings (Tikhiy et al., 2021). Powders were hydrated at a ratio of 1:5 powder to water, at the water temperature of 30 °C, for 40 min. The thick sourdough with a moisture content of about 40% was prepared.

The amount of water introduced into the sponge was adjusted according to the moisture-binding ability of the powders (Koryachkina et al., 2015) and the amount of water used for hydration (if hydrated powders were introduced).

Table 3. Sourdough recipe with powders added and with no powders added

Raw material	Sample type		
	No powders	With dry powders	With hydrated powders
Premium wheat flour, g	50.0	50.0	50.0
Pressed yeast, g	1.25	1.25	1.25
Drinking water, g	25.0	26.45	26.45
Dry carrot/beetroot powder, g	0	3.0	0
Hydrated carrot/beetroot powder, g	0	0	3.0
TOTAL, g	76.25	80.70	80.70

A KitchenAid 5KSM175PSECA mixer mixed the sourdough for 2 minutes at the first speed rate and 1 minute at the second speed rate. The fermentation process took 120 min. After it, the dough was mixed. The dough recipe is shown in Table 4.

The amount of water added to the dough was adjusted according to the moisture-binding ability of the powders and the amount of water used for hydration (if hydrated powders were introduced) so that the humidity was 32.5%.

The dough was mixed on a *KitchenAid 5KSM175PSECA* mixer at the first speed rate for 3 minutes and 1 minute at the second speed rate. After it, it was held for 10 min and divided into 43 g blanks. Then, they were rounded and molded into round cracknels.

Table 4. The round cracknels recipe

Raw material	Sample type				
	Control sample	1.5%	3%	6%	9%
Premium wheat flour, g	200.0				
Sunflower oil, g	20.0				
Salt, g	3.75				
Sugar, g	22.5				
Sourdough, g	76.25	80.7	80.7	80.7	80.7
Dry carrot/beetroot powder*, g	0.00	0.75	4.50	12.00	19.50
Drinking water, g	85.00	85.20	86.90	90.10	92.10
TOTAL, g	407.50	412.90	418.35	429.05	438.55

*When mixing the dough and the dry powder, the dry powder was added to the dough. When mixing the dough with the addition of the hydrated powder, the hydrated powder was added to the dough.

The products were baked at a temperature of 214 °C for 11 minutes. At the end of baking, the products were cooled to a temperature of 23 °C. After that, the physical and chemical properties of the end products were analyzed. During the experiment, the proofing time for all samples was 55 min.

The sourdough acidity was calculated by dissolving 5 g of the sample and then potentiometric titration with the standardized sodium hydroxide (NaOH) to pH 8.0. Acidity was determined using the titration method, and the results were presented in degrees according to GOST 5670 (1996); the pH was measured with a pH meter *Testo 206-pH1* (Kobus-Cisowska et al., 2020).

To determine the acidity of the end products, 10 g of crumb and 100 cm^3 of distilled water at a temperature of 18–25 °C were placed in a volumetric flask of 250 cm^3. Subsequently, the sample was shaken to reach homogeneity and allowed to settle for 15 min. 25 cm^3 of the filtrate were extracted and exposed to potentiometric titration with the standardized solution of sodium hydroxide (NaOH) to pH 8.0 (GOST 5670, 1996).

The moisture of the sourdough, the dough, and the end products was determined by drying test portions at 160 °C for 5 min and calculating the percent of the weight difference between the original sample and the dry one (GOST 21094, 1975).

The swelling coefficient of the end products was determined by comparing the weights of dry pieces of the product (2 cm long) to the weights of the swollen parts, which had been held in a water bath for 5 minutes, at a water temperature of 60 °C (GOST 32124, 2013).

In the study, conventional research methods were used. All the values were reported as mean ± SD. All treatments and analyses were performed in triplicate for each sample. The statistical processing of the obtained results was carried out by conventional methods (assessing the significance according to Fisher's and Student's criteria) using the *Microsoft Excel* software package.

RESULTS AND DISCUSSION

The particle size of powders and flour affects the quality and mode of dough preparation and the biochemical and colloidal processes occurring when the powders and the flour are interacting with the water (Qin et al., 2021).

The results of the particle size distribution analysis for flour and carrot/beetroot powders are presented in Table 5.

The beetroot powder has a more acceptable particle size than the carrot powder. As shown in the table, 100% premium flour particle size range from 0 μm to 200 μm. 77% of the carrot powder particles and 71% of beetroot powder particles range from 0 μm to 200 μm (the same diapason), comparable to the flour particle size.

Table 5. The particle size distribution analysis of the premium wheat flour and carrot/beetroot powders

Particle size, μm	Percentage of particles in the grind, %		
	Flour	Carrot	Beetroot
0–50	41.85	39.20	45.89
50–100	27.86	19.32	21.97
100–200	30.29	18.96	3.33
200–500	-	6.67	-
500–1,000	-	8.21	-
1,000–2,000	-	7.64	28.81

To study the impact of the powders on the structural and mechanical properties of the dough, their effect on the quantity and quality changes of gluten was determined.

The flour samples without and with dry powders of carrots or beetroots added in 1.5%, 3.0%, 6.0% and 9.0% were prepared (Table 6).

As shown in the table, when dry carrot powder is added to the flour in an amount of 1.5%, 3.0%, 6.0% and 9.0%, the gluten content decreases from 31.3% to 30.2%; 29.1%; 28.8%; 27.5% respectively, and when adding beetroot powder in the same amount - from 31.3% to 30.6%; 29.7%; 29.0%; 28.3% respectively.

Table 6. Indicators of the quantity and quality of gluten in samples with and without powders

Indicator	Sample type								
	No powder	Carrot powder				Beetroot powder			
		1.5%	3.0%	6.0%	9.0%	1.5%	3.0%	6.0%	9.0%
Dry gluten quantity, %	31.30	30.21	29.12	28.83	27.52	30.63	29.75	29.02	28.34
Gluten quality, units	68.73 ± 0.48	59.80 ± 0.54	58.50 ± 0.40	58.00 ± 0.52	55.35 ± 0.54	66.90 ± 0.51	60.00 ± 0.53	55.30 ± 0.46	50.05 ± 0.54

The partial replacement of the premium wheat flour with the carrot and beetroot powders caused a decrease in the total gluten content of the test samples.

The change in the gluten elastic properties was measured with the gluten deformation measuring device and expressed in units (gluten quality units). When carrot powder is added to the flour in an amount of 1.5%, 3.0%, 6.0% and 9.0%, the quality of gluten, and its deformation, measured with the gluten deformation measuring device, decreases from 68.7 to 55.3 units. When the same amount of beetroot powder is added to the flour, the gluten deformation index decreases from 68.7 down to 50.0 units, depending on the amount of powder added.

The decrease in the deformation index increases the elastic properties of gluten and indicates its strengthening according to GOST R 54478 (2011), which is crucial to the formation of product porosity. Due to carbon dioxide released during the fermentation, gluten is stretched, and the structure and porosity are formed. In the technology of round cracknels preparation, the fermentation process occurs when preparing the dough and during the after fermentation process while proofing. The influence of vegetable powders on the fermentation of sourdough was estimated by the change in acidity (Table 7).

Table 7. Physical and chemical properties of the sourdough with and without powders added

Indicator	Sample type				
	No powder	Carrot powder		Beetroot powder	
		dry	hydrated	dry	hydrated
Moisture, %	35.82 ± 0.46	36.21 ± 0.55	35.92 ± 0.48	36.34 ± 0.42	35.90 ± 0.51
Acidity, deg.	3.80 ± 0.11	4.00 ± 0.12	4.20 ± 0.10	4.00 ± 0.11	4.20 ± 0.10

The change in the dough acidity when introducing the dry powders is insignificant and is within the margin of error. The dough acidity changed by 0.2 deg when submitting to the hydrated powders. In powder hydration, some components pass into a dissolved state. It explains the increase in the rate of nutrient entry into the yeast cell, the activation of the vital activity of yeast and, as a result, the increase in the amount of organic acids produced by the yeast cell.

The dough was mixed according to the recipe (Table 4). The effect of vegetable powders on the dough fermentation process was estimated by the change in the acidity of the end dough (Tables 8 and 9).

Table 8. Physical and chemical properties of the dough with and without carrot powder added

Indicator	Sample type								
	Control sample	Carrot powder							
		Dry				Hydrated			
		1.5%	3.0%	6.0%	9.0%	1.5%	3.0%	6.0%	9.0%
Moisture, %	32.51 ± 0.51	32.71 ± 0.54	32.84 ± 0.49	33.12 ± 0.50	33.21 ± 0.51	32.42 ± 0.53	32.54 ± 0.51	32.71 ± 0.50	32.91 ± 0.54
Acidity, deg.	2.80 ± 0.10	3.00 ± 0.11	3.00 ± 0.10	3.20 ± 0.12	3.20 ± 0.11	2.80 ± 0.11	3.00 ± 0.10	3.20 ± 0.11	3.20 ± 0.11

After the mixture process, the dough with carrot and beetroot powders added was smooth and elastic, with no under mixing.

The results presented in Tables 8 and 9 showed increased acidity when the dry and the hydrated powders were used. In the sample with no powders added, the acidity is 2.8 deg. With the introduction of the powders, the acidity increases to an average of 3.0–3.2 deg.

Table 9. Physical and chemical properties of the dough with and without beetroot powder added

Indicator	Sample type								
	Control sample	Beetroot powder							
		Dry				Hydrated			
		1.5%	3.0%	6.0%	9.0%	1,5%	3.0%	6.0%	9.0%
Moisture, %	32.51 ± 0.51	32.52 ± 0.50	32.72 ± 0.51	33.01 ± 0.52	33.13 ± 0.51	32.46 ± 0.54	32.65 ± 0.51	32.80 ± 0.53	32.91 ± 0.50
Acidity, deg	2.80 ± 0.10	3.00 ± 0.10	3.20 ± 0.12	3.20 ± 0.11	3.40 ± 0.11	3.00 ± 0.10	3.20 ± 0.12	3.20 ± 0.10	3.40 ± 0.11

The organic acids added to the carrot and beetroot powders caused the increase in dough acidity. Moreover, the fermentation process occurs during the proofing. The microelements, which are parts of the powders (including organic acids), cause the vital activity of the yeast, leading to an increase in the new organic acids formation (Garzon et al., 2021). Acidity is determined at the end of the proofing process. Therefore, a faster increase in acidity causes a reduction in the technological operation time. Moreover, the rise in dough acidity leads to an increase in organoleptic characteristics of the end products.

The fermentation process activation when adding the vegetable powders leads to an increase in dough acidity and a change in the dough structure and its porosity (Yano et al., 2017). The addition of pectin and dietary fiber to the vegetable powders affects the interaction processes of finished products with water, their wettability and swelling. There will be a decrease in the amount of carbohydrates and flour proteins, which affects the colloidal system of the dough and the end products. Porosity, wettability and the state of the colloidal system affect swelling, an essential indicator for round cracknel products.

The acidity and the swelling coefficient of the end round cracknels are presented in Tables 10 and 11.

Table 10. Physical and chemical properties of the end products with and without carrot powder added

Indicator	Sample name								
	No powder	Carrot powder							
		Dry				Hydrated			
		1.5%	3.0%	6.0%	9.0%	1.5%	3.0%	6.0%	9.0%
Moisture, %	20.10 ± 0.50	19.71 ± 0.53	20.45 ± 0.51	20.37 ± 0.54	20.70 ± 0.51	19.74 ± 0.51	19.85 ± 0.52	19.97 ± 0.50	19.71 ± 0.51
Acidity, deg	2.60 ± 0.10	2.80 ± 0.11	2.80 ± 0.12	3.00 ± 0.12	3.00 ± 0.11	2.60 ± 0.10	2.80 ± 0.11	3.00 ± 0.10	3.00 ± 0.12
Swelling coefficient	4.12 ± 0.11	5.78 ± 0.12	5.52 ± 0.14	5.44 ± 0.12	4.65 ± 0.16	6.76 ± 0.11	6.15 ± 0.14	5.14 ± 0.12	4.86 ± 0.11

Table 11. Physical and chemical properties of the end products with and without beetroot powder added

Indicator	Sample name								
	No powder	Beetroot powder							
		Dry				Hydrated			
		1.5%	3.0%	6.0%	9.0%	1.5%	3.0%	6.0%	9.0%
Moisture, %	20.10 ± 0.50	20.75 ± 0.5	20.54 ± 0.5	20.87 ± 0.5	20.62 ± 0.5	20.28 ± 0.5	19.83 ± 0.5	19.94 ± 0.5	19.84 ± 0.5
Acidity, deg	2.60 ± 0.10	3.00 ± 0.11	2.80 ± 0.10	3.00 ± 0.12	3.00 ± 0.10	2.60 ± 0.10	2.80 ± 0.12	3.00 ± 0.11	3.00 ± 0.1
Swelling coefficient	4.12 ± 0.11	4.84 ± 0.13	4.77 ± 0.14	4.4 ± 0.12	4.12 ± 0.1	5.53 ± 0.15	4.84 ± 0.12	4.62 ± 0.11	4.15 ± 0.13

The results presented in Tables 10 and 11 show that the dry carrot powder added in an amount of 1.5% increases the swelling coefficient of the end product from 4.1 to 5.7. When the hydrated powder is added, it increases from 4.1 to 6.7. The increase in the swelling coefficient after adding the hydrated powder can be explained by an increase in the yeast fermentation activity (the data on increased acidity are presented in Table 7, Table 8 and Table 9). Therefore, by the amount of carbon dioxide released, the formation of a more porous structure of the product and the swelling coefficient increase. The difference between the swelling coefficient in the end products when dry and hydrated carrot powders are added remains even with an increase in the powder application dose.

But with an increase in the powder application dose, this difference will decrease, which is explained by a decrease in the amount of carbohydrates and proteins introduced with the flour, which affects the colloidal system of the product and, as a result, the swelling.

The tendency remains when the dry and the hydrated beetroot powders are added to the sourdough and the dough. Still, the difference between the swelling coefficient increase and the addition of the hydrated beetroot powder is less than with the hydrated carrot powder added. The introduction of dry carrot powder leads to an increase in the swelling coefficient of the end products by an average of 15%. In comparison, introducing the hydrated carrot powder in the same amount into the sourdough and the dough increases the swelling coefficient by 40%. The introduction of the dry beetroot powder leads to an increase in the swelling coefficient of the end products by an average of 12%. In comparison, introducing the hydrated beetroot powder in the same amount in the sourdough and the dough increases the swelling coefficient by 22%. This is due to the different chemical compositions of the carrot and beetroot powders and the different amounts of polar and non-polar substances.

CONCLUSIONS

The results obtained in this study prove the effectiveness of introducing vegetable powders, particularly carrot and beetroot ones, into the recipe of round cracknel products. The introduction of powders increased the quality indicators of the end products, i.e. acidity and swelling. The introduction of powders in a dry and prehydrated form, particularly into the sourdough and the dough, increased the quality of gluten and its elasticity, making it possible to increase the swelling of the round cracknels. The study has demonstrated the positive effect of the preliminary hydration of dry carrot and beetroot powders before adding them to the sourdough and the dough in round cracknels production. Thus, according to the results, further research is needed to study the feasibility of pre-hydration of the powders obtained from the other types of vegetable crops and provide evidence of the effectiveness of including hydrated vegetable powders in various bakery products.

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