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Effect of dough making parameters on the quality of pasta enriched with bran dietary fibers

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For use of bran in pasta production, it is advisable to study how it influences the quality of the product and to determine the optimal parameters of dough making.

Wheat flour second grade was used as the main raw material. The organoleptic and cooking properties of the pasta its physical and chemical quality characteristics were determined. The structure of the dough samples was studied by scattering the batch onto the system of metal sieves and determining the mass of dough fractions. Mathematical modeling of kneading process was applied and the regression equation that describes how dry matter passage in cooking water depends on bran dosage, dough moisture and water temperature were determined.

It was established herewith that addition of more bran leads to poor product tenacity and the amount of dry matter passing into the cooking water increases. The increase in moisture and kneading time improves the product tenacity, increases the productivity of the press, and reduces the amount of dry matter passing into the cooking water.

Thus, the maximum bran dosage that ensures the production of pasta of acceptable quality is 20 %. For the best quality, the following parameters must be observed: moisture 36 %, temperature of water 60 ºC and kneading time 20 minutes.

Keywords: pasta, wheat bran, dough making, quality, mathematical models, parameter optimization.

Introduction

Modern science proved the necessity of dietary fibers consumption for human health. The deficiency of dietary fibers results in the decrease of body resistance against negative environmental effects and diseases.

Wheat bran is one of the sources of dietary fibers. It contains a significant amount of dietary fibers that are insoluble but not absorbed by the human body; however, they are important for normal digestion. Bran acts as an adsorbent playing an important role in prevention and treatment of excessive weight, diabetes, hypertension, cardiovascular disease and cancer. Bran fibers contain B vitamins, strengthen nervous system, and improve metabolism and skin condition.

Wheat bran is extensively used for enhancing food with dietary fibers in bread baking, making pastry, food concentrates and some dairy products [1–8]. At one time the recipes were developed for the pasta with 30 % wheat bran (TU (Technical Conditions of Ukraine) 8-22-63-88), which, as our research [9] shows, is unreasonable in terms of ensuring the acceptable organoleptic properties of the products. The technology for making the pasta enriched with dietary fibers has neither been researched, nor covered in the literature.

Recently due to wide use of advanced flour production technologies, particularly the production lines of "Buller" company, it has become possible pick up embryos off bran mass. There have also been drafted new bran regulations, namely for fodder wheat and rye bran (DSTU (State Standard of Ukraine) 3016-95) and dietary wheat and rye bran (TU U 00951706-004-98). They differ in chemical composition, particle dimension, and, therefore, differ in technological properties.

In order to develop a technology for the production of the pasta with wheat bran, it is necessary to examine how the addition of bran influences the product quality. It is also important to determine the appropriate bran dosage and to study the production technology.

The objective of this study is to determine the optimal dosage of bran, also to examine the influence of dough making parameters on the properties of dough containing wheat bran, and to determine the optimal parameters for making such dough.

Materials and Methods

The second grade flour is used as the main raw material for producing the pasta enriched with dietary fibers. The feasibility of this solution is explained by a higher content of dietary fibers in the second grade flour compared to the first grade flour. But the second grade flour contains less gluten that may lead to the significant decrease of tenacity and cooking properties of the products. Therefore, the flour with gluten content higher than the standard was used. The quality of the flour was characterized by the following parameters: moisture 12.2 %, content of gluten 27 %, gluten resilience 47 unit measured by the IDK device. The quality of dietary wheat bran met the TU 00951706-004-98 standards: moisture 13.2 %, acid number of fat 43.6 %, acidity 12 degree. The content of dietary fibers was calculated as 38.39 % [9].

Bran was added in proportions of 10 %, 15 %, 20 %, 25 %, and 30 % per flour mass. The dough was kneaded by a laboratory press using the method of warm kneading for 10 minutes. The raw pasta was shaped as noodles.

The organoleptic and cooking properties of the pasta were determined, as well as its physical and chemical quality characteristics, including moisture, acidity and strength (GOST 14849).

For determining the effect of dough moisture on the properties of dough and quality of the finished product, the moisture was 35 %, 36 %, 37 %, and dosed of bran was 20 %.

To study the effect of temperature and kneading time on the properties of the pasta dough, and the product quality, warm kneading with water of 50 ºC, 60 ºC and 70 ºC for 10 and 20 minutes was used.

The structure (crumbliness) of pasta dough samples was studied by scattering the batch onto the system of metal sieves (No. 7, 5, 3, 1) and by determining the mass of dough fractions different in size according to the methodology [10]. The amount of crumbs of each dough fraction was proportioned in percentage per batch. The speed of pasta extrusion (mm/s) was determined by measuring the length of the raw product extruded within 30 seconds. The productivity of the press, kg/h, was determined by weighting the product.

For the mathematical description of dough kneading we used the method of experimental and statistical modeling using multivariate mathematical planning of the experiment. Upon implementation of the experiment, we carried out statistical analysis of the results, including the identification of errors, calculation of regression coefficients of the mathematical model, assessment of the significance of mathematical model and verification its adequacy. Based on the obtained mathematical models, the optimization of the process was performed using the Box-Wilson [11] complex method. Each series of the experiments was repeated four times. By measuring the basic quality factors of semi-finished and finished products, a sample sufficient for statistical processing was identified.

The content of cellulose was determined by titrometric methods according A.I. Ermakova's modification [12]. The establishment of the total content of hemicellulose and lignin was carried out by the methods described in [13]. The total number of dietary fibers was calculated. The content of dietary fibers in pasta was determined by the way of calculation.

Research results and discussion

The results of the experiment aimed at studying the impact of various bran dosages on the product quality are listed in Table 1.

The analysis of the data has proved that addition of bran to the dough significantly affects the quality of the pasta. It was also established that with addition of bran the color of the product darkens. The product's surface changes from smooth in control and at 10 % bran dosage, to barely rough at 15 % and 20 % bran dosage, and to very rough at 25 % or more bran dosage. The taste quality of cooked products, compared to control samples, does not change; however, during chewing more bran particles can be found when bran dosage is increased to 25 % and to 30 %. With the increase of bran dosage, naturally the acidity of the products increases and tenacity reduces.

Table 1. The effect of bran dosage on the quality of macaroni products

Quality index	Characteristics of products with the addition of bran					
	Control (bran free)	wheat bran, % to the weight of flour				
		10	15	20	25	30
Organoleptic characteristics						
Colour	brown	brown, with slight patches of bran particles			dark brown, with large patches of bran particles	
Surface	smooth		rough			very rough
Fracture	glassy		half-glassy		non-glassy	
Micro-cracks	absent					
Physical and chemical characteristics						
Moisture, %	9.8±0.2	9.9±0.2	10.0±0.2	10.0±0.2	10.1±0.2	10.1±0.2
Acidity, degree	5.4±0.2	5.8±0.2	6.3±0.2	6.7±0.2	7.1±0.2	7.4±0.2
Strength, H	6.3±0.1	5.9±0.1	4.7±0.1	4.1±0.1	4.1±0.1	3.5±0.1
Cooking properties						
Shape	retain their shape, do not stick					
Taste and odour	typical for the kind of the product	with slight taste of bran			with strong taste of bran	
Mass increase index, Mi	1.5±0.1	1.4±0.1	1.4±0.1	1.4±0.1	1.4±0.1	1.4±0.1
Volume increase index, Vi	1.8±0.1	1.8±0.1	1.8±0.1	1.8±0.1	1.8±0.1	1.9±0.1
The amount of dry matter passed in cooking water, %	9.8±0.2	10.7±0.2	11.2±0.2	11.8±0.2	12.2±0.2	12.5±0.2
Cooking time, min	18					

Passing of dry matter into cooking water (in a control sample) increases by 1.0–2.0 % at 10 % and 20 % bran dosage, respectively; at higher dosages it is excessively high (12.2 % and 12.5 %). It should be noted that the overall dry matter passing into cooking water in this series of experiments was quite high due to the technological properties of bread flour that was used.

Therefore, the maximum bran dosage for pasta products of acceptable quality makes 20 %.

The results of the effect of moisture on the properties of the dough and the quality of pasta products are shown in the Table 2.

As the study demonstrates, the growth of dough moisture causes the increase of larger particles (residues of the sieves No. 7, No. 5 and No. 3). Such a redistribution of fractions happens mainly due to reducing the output of the sieve No.1. At the same time, the smallest fraction output of the sieve No. 1 slightly increases. It is known that the increasing of dough moisture makes the dough more crumbled. It is known that the increase of dough moisture naturally accelerates the extrusion and the performance of the press. However, the excessive increase of large crumbs is undesirable as auger turns will not be well filled by dough and the process of extrusion may slow down.

The influence of moisture on the quality of the pasta was decisive for determining the required moisture. Organoleptic and cooking properties demonstrated that that the surface of the product changed from rough to barely rough when moisture increased. The best quality is observed at 37 % moisture content. The products are of the best strength, the highest mass index increases and the highest volume index increases too, as well as the least amount of dry matter passes into the cooking water. But the raw products of such dough were too flexible resulting in loss of shape. Therefore, it is advisable to prepare the dough with moisture content of 36 %. It is of average crumbliness, the auger turns are well-filled, and in terms of quality, the product is almost identical to the one made of the dough with moisture content of 37 %.

Table 2. The effect of dough moisture with the addition of 20 % wheat bran on the quality of the dough and pasta products

Quality index	Moisture content, %		
	35	36	37
Dough:			
Crumbliness (residue on the sieve No, %):			
No. 7	0.8	2.4	4.8
No. 5	0.6	1.2	2.2
No. 3	11.0	16.4	17.4
No. 1	80.0	71.4	58.8
Passing through the sieve No. 1	7.6	8.6	8.0
Pressing speed, mm/sec	13.0	14.6	15.0
Press efficiency kg/hour	13.2	13.9	14.4
Macaroni products:			
Organoleptic characteristics			
Colour	brown		
Surface	rough	slightly rough	
Fracture	half-glassy		
Physical and chemical characteristics			
Moisture, %	10.0±0.2	10.0±0.2	10.0±0.2
Acidity, degree	7.2±0.2	7.2±0.2	7.2±0.2
Strength, H	2.9±0.1	3.5±0.1	3.7±0.1
Cooking properties			
Shape	retain their shape		
Taste and odour	inherent in this type of products, there is the taste of bran		
Mass increase index, Mi	1.3±0.1	1.4±0.1	1.4±0.1
Volume increase index, Vi	1.6±0.1	1.6±0.1	1.7±0.1
The amount of dry matter passed in cooking water, %	8.4±0.2	8.3±0.2	8.2±0.2

The results of the study on the effect of water temperature and kneading time on dough crumbliness and product quality are shown in Fig. 1, 2 and Table 3.

As we see (Fig.1), with the increase of water temperature from 50 ºC to 60 ºC there is a tendency to generate large crumbles: the residues on the sieves No. 7, No. 5, No. 3 increase and the residue on the sieve No.1 is 2–3 % is lower. Further increase of the temperature to 70 ºC does not significantly affect the dough crumbliness. It should be noted that simultaneously with the increase of the temperature of water, the passage through the sieve No. 1 is twice as much intense. Thus, within certain limits the dough becomes less homogeneous with regards to the size of crumbles. Generally, if the temperature of water for kneading is 50–70 ºC the change of the dough crumbliness becomes insignificant.

The increase of kneading time from 10 minutes to 20 minutes at the temperature of 50 ºC leads to the increase of large crumbs (residues of the sieves No.7–No. 3) and the decrease of small crumbs (residue of the sieve No.1) (Fig. 2). At the temperature of 70 ºC the increase of kneading time to 20 minutes almost does not have any effect on dough crumbliness. Obviously, at 50 ºC, the swelling of flour colloids is slower, and the extension of kneading time intensifies the process and increases cohesion force. If the temperature of water is 70 ºC, the colloidal process is accelerated, and the required level of crumbliness is already sufficient after 10 minutes of kneading.

The study on the influence of water temperature and dough kneading time on the quality of the pasta, demonstrates that the increase of water temperature and kneading time improves the quality of the product, namely mass rate and product strength increases, dry matter that passes in cooking water decreases. This can be explained by the fact that the plasticity and density of the dough increases in proportion to the increase of temperature, thus, the dough tenacity improves eventually.

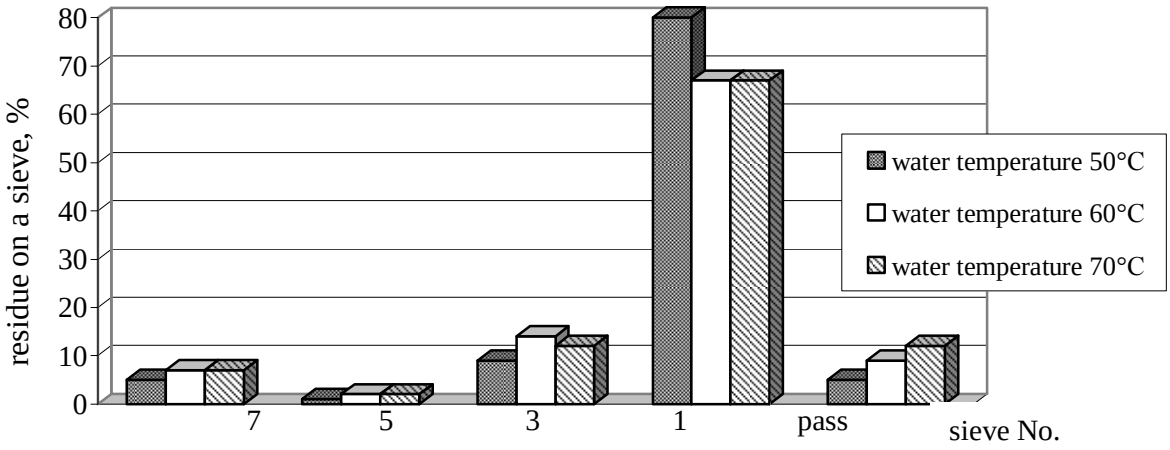

Fig. 1. The influence of water temperature used for kneading on the dough crumbliness

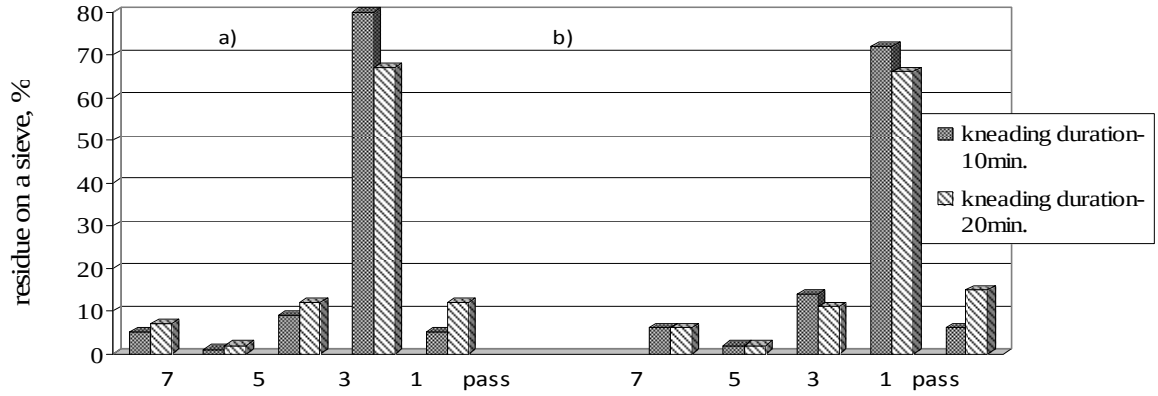

Fig. 2. The influence of kneading time on the dough crumbliness: a) 50 °C; b) 70 °C

Table 3. The influence of water temperature and kneading time with 20 % wheat bran on the quality of pasta products

Quality index	Kneading time, min.					
	10			20		
	Water temperature, °C					
	50	60	70	50	60	70
Organoleptic characteristics						
Colour	brown, with slight patches of bran particles					
Surface	rough					
Fracture	half-glassy					
Physical and chemical characteristics						
Strength, H	3.3±0.1	3.4±0.1	3.5±0.1	3.5±0.1	3.7±0.1	3.7±0.1
Cooking properties						
Colour	brown, with patches of bran particles					
Shape	retain their shape					
Mass increase index, Mi	1.4±0.1	1.5±0.1	1.5±0.1	1.4±0.1	1.5±0.1	1.5±0.1
Volume increase index, Vi	1.8±0.1			1.8±0.1		
The amount of dry matter passed in cooking water, %	9.2±0.2	9.4±0.2	9.0±0.2	9.2±0.2	9.0±0.2	8.8±0.2
Duration of cooking, min	17			18		

The best quality of the product is achieved with 10 minutes of kneading time, with water temperature 70 ºC, and kneading for 20 minutes, with water temperature 60 ºC, does not cause any changes. In general, the extension of kneading time to 20 minutes contributes to the improvement of the quality of the product.

Thus, to achieve the best quality of the product, the recommended time of kneading should be 20 minutes and the temperature of water 60 ºC.

To reason the optimum parameters of the dough making, it is important to study the effects of various factors on the relationship of the properties of the dough and the finished product. For this purpose, simulation and optimization of pasta dough kneading and extrusion was carried out.

The research was carried out by the Box-Wilson method. Certain amount of bran (X_1), dough moisture (X_2) and water temperature (X_3) were selected as optimizing factors. Considering the nonlinear nature of the impact of the factors on the output variables, the polynom of the second degree was applied for its mathematical description. The PFE 2^3 was applied.

The factor of the product's dry matter passing into cooking water was taken as an optimum criterion. The dependence of the above factor was determined depending on the optimizing factors.

The levels of the factors and the interval of their variation are shown in the Table 4.

On the basis of the previous research, 36 % dough moisture was chosen as a zero level. The dosage of bran and water temperature changed within 15–25 % and 50–70 °C respectively.

Table 4. Ranges of quotient space

Factor levels	Legend	Factors under the research		
		bran amount (X_1), %	dough moisture (X_2), %	water temperature (X_3), °C
Zero level	X^0_i	20.0	36.0	60
Variation range	λ_i	5.0	1.0	10
Lower level	X^-_i	15.0	35.0	50
Upper level	X^+_i	25.0	37.0	70

Based on the experiment and on the processing of the experimental data, the following dependencies in coded and natural expressions were obtained:

regression equation for Y – dry mater passing into cooking water:

in coded expression

$$Y=8.275+0.575\ X_1-0.150\ X_2-0.050\ X_1\ X_2-0.025\ X_2\ X_3$$

in natural expression

$$Y=-1.1336+0.4728\ X_1+0.1989\ X_2-0.0099\ X_1\ X_2-0.0024\ X_2\ X_3$$

The obtained mathematical models adequately describe the experimental data. It is proved by calculated values of the Fisher's criterion 0.125 and 0.5987 respectively, if $F_1=5.59$;

$X_1=15$ %; $X_2=37$ % corresponded to the optimum function $Y_{min}=7.6$; X_3 was an insignificant factor.

The minimal value of the function on the rate of conversion of dry matter in cooking water is achieved with the minimum bran dosage and the maximum dough moisture.

The results of optimization showed that the optimum rate of conversion of dry matter in cooking water was achieved with 15 % bran dosage and 37 % dough moisture, while the temperature was an insignificant factor. If the dough moisture is 35 %, the products have rough surface, and with the moisture of 37 % the products may be deformed during extrusion. Taking into account the above-mentioned, the optimal dough moisture may be considered 36 %.

According to the calculation, the content of the dietary fibers in the pasta enriched with 15 % and 20 % bran is 9.2 % and 10.4 % respectively [9].

Therefore, with regard to all the technological factors, the best quality of the product can be achieved by using 15 % bran. However, by increasing bran dosage up to 20 %, the acceptable quality of the product can be achieved along with the significant enrichment of dietary fibers. The strength factor and dry matter passing into cooking water decreases by further increasing of bran dosage. Therefore, in order to improve the quality of the pasta by increasing the bran dosage, it is necessary to apply additional techniques, and the use of food additives improving the product structure may be one of such techniques [9].

Conclusions

1. The maximum bran dosage that ensures the production of the pasta of acceptable quality is 20 %. In order to increase fiber content in the pasta by using a greater amount of bran it is

necessary to apply additional techniques that would help to improve the quality of the product

2. The dough kneading simulation was carried out and the regression equation that described how dry matter passage in cooking water depends on bran dosage, dough moisture and the water temperature for kneading was determined. The optimum parameters of the dough making with the minimum passage of dry matter into cooking water were defined.
3. It is advisable to make dough using 20 % bran, 36 % moisture and to apply warm kneading (water temperature 60 ºC) for 20 minutes in order to achieve maximum enrichment of the pasta with dietary fibers.

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TEŠLOS RUOŠIMO PARAMETRŲ ĮTAKA TEŠLOS SAVYBĖMS IR PAPILDYTŲ SĖLENŲ SKAIDULOMIS MAKARONŲ KOKYBEI

Santrauka

Siekiant panaudoti kviečių sėlenas makaronų gaminių gamyboje, tikslinga ištirti jų įtaką gaminių kokybei, nustatyti pridedamų sėlenų kiekį ir optimalius tešlos ruošimo parametrus. Pagrindinė žaliava makaronų gamybai buvo antros rūšies minkštųjų kviečių miltai. Nustatytos makaronų gaminių juslinės ir virimo savybės, kokybės fizikiniai cheminiai rodikliai. Makaronų tešlos struktūra tirta, sijojant mėginį metaliniais sietais ir nustatant tešlos frakcijų masę. Aprašant matematiškai makaronų tešlos maišymo procesą, jis modeliuotas, ir gauta regresijos lygtis, parodanti virimo nuostolių (sausųjų medžiagų perėjimo į virimo vandenį) rodiklio priklausomybę nuo sėlenų kiekio, tešlos drėgnio ir maišymui naudojamo vandens temperatūros. Tyrimų rezultatai parodė, kad sėlenų priedas mažino gaminių stiprumą ir didino virimo nuostolius. Didinant tešlos drėgnį ir ilginant maišymo trukmę, didėjo tešlos struktūros kruopiškumas, makaronų gamybos preso našumas, gaminių stiprumas, mažėjo virimo nuostoliai.

Nustatyta, kad didžiausias sėlenų kiekis, užtikrinantis priimtinos kokybės makaronų gaminių gamybą, yra 20 %, tešlos drėgnis – 36 %. Geriausia gaminių kokybė pasiekta, esant maišymui naudojamo vandens temperatūrai 50–60 ºC, tešlos maišymo trukmei – 20 min.

Raktažodžiai: makaronų gaminiai, kviečių sėlenos, tešlos maišymas, kokybė, matematiniai modeliai, parametrų optimizavimas.