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PHYSICAL PROPERTIES OF EXTRUSION-COOKED VEGETABLE RAW MATERIALS

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A b s t r a c t. Study results on the selected physical properties of extrudates obtained from various cereals, legume and oleaginous seeds processed in a twin-screw extruder are reported in the paper.

Influence of baro-thermal process parameters: temperature, pressure, die's size, screw's rotational speed on the expansion ratio and the water absorption index of the extrudates was examined.

The results obtained were used to define relationships between extrusion-cooking process parameters and quality of the products received from different raw materials.

K e y w o r d s: extrusion-cooking, physical properties

INTRODUCTION

Research on the extrusion-cooking of vegetable raw materials and the effect of the process parameters on the physical properties of extrudates has been carried out in the Department of Food Process Engineering at the Lublin University of Agriculture, Poland.

The initial results of the research on the physical properties of the extrudates obtained from 16 materials and crop mixtures (cereals, leguminous and oil plants seets) processed in a Valeurex type twin-screw extruder are presented in the paper. Harper [2] and Guy [1] evidenced that the extrusion-cooking variable parameters affect the quality of the processed raw materials. The moisture content and chemical composition of the mixture also have great influence on the final product. In our research, attention has been focused on the expantion ratio (*S.E.I.*) and the water absorption index (*WAI*) of the various extrudates in relation to the raw material used, especially mixtures of different materials (with different starch and protein content). These properties are very useful for snack producers due to the importance of snack quality parameters, their packaging and storage conditions. *WAI* is important due to fact that direct extrusion corn snacks are often used here as r.t.e. breakfast cereals.

MATERIALS AND METHODS

Extrusion-cooking was carried out in a counter rotating twin-screw extrusion-cooker, type Valeurex (L/D = 20/1) driven by 75 kW motor. The working capacity of the extruder varied from 260 to 380 kg h^{-1} subject to the raw material used. The extruder die head had 16 holes, 5 mm in diameter each.

Distribution time of the process was in a range 45-65 s. Processing temperature in the main section of the extruder varied from 150 to 200 ^{o}C.

The following materials were used for the present research: maize, barley, wheat oat, rye, rice, broad beans, lupine, rape seeds and rape cake, soya, potato starch. Proximate analysis of their chemical composition are given in Table 1.

The materials were ground in the hummer mill, type H 111/3 made in the Polish, to receive suitable form: grits 0.1-1.0 mm; a meal 1.0-3.0 mm; a flour 0.01-0.05 mm after sifting into 3 fractions. They are the most common used by local industry.

Table 1. Chemical composition of raw materials

No.	Material	Crude protein	Carbo-hydrates	Fat	Fiber	Ash
1.	Wheat meal	13.2	53.2	1.8	3.0	1.9
2.	Oat meal	10.1	36.1	4.7	10.7	3.2
3.	Barley meal	11.5	50.1	2.0	4.3	2.4
4.	Rye meal	13.0	54.0	1.8	2.6	2.1
5.	Maize grits	9.8	59.8	4.0	2.1	1.2
6.	Soya grits	48.0	35.0	25.0	1.8	5.0
7.	Rape seed meal	24.0	18.0	45.0	1.0	0.4
8.	Rape seed cake meal	35.0	29.3	0.5	1.7	0.7
9.	Broad beans meal	28.7	56.9	1.6	9.0	3.0
10.	Lupine meal	44.3	31.4	5.2	1.4	4.4
11.	Rice grits	7.8	55.2	2.3	1.3	1.3

Material mixtures were obtained by means of a drum mixer (10 min of mixing time) into which water was added to obtain varied moisture levels (from 14 to 25% of dry basis).

The extrudates obtained were dried in room temperature for 24 h to stabilise their physical properties.

Water absorption index of the extrudate was determined according to following formula [1]:

$$WAI = \frac{M_w - m}{m} 100\% \qquad (1)$$

where: M_W - volume of water absorbed by the product (g), m - sample dry matter weight (g).

Procedure: Extrudates samples of 10 g weight were moistened in water at the temperature of 8 °C for 20 min, to be subsequently bled on a sieve for 10 min and weighted. Measurements of each product were made in 6 repetitions.

The expantion of the extrudate ratio was determined according to the following formula [1,2]:

$$S.E.I. = \frac{D}{d} \qquad (2)$$

where: $S.E.I.$ - sectional expansion index, D - diameter of the cross-section of an extrudate (mm), d - diameter of the die hole (mm).

The measurements of each product were made by means of a slide calliper with the measuring accuracy of 0.1 mm in 20 repetitions.

RESULTS

The selection of results on water absorption index and expantion ratio are presented in Table 2. The properties shown here are the main characteristic taken from more than 60 samples (mixtures).

CONCLUSIONS

1. During extrusion-cooking, approximately 5-6.5% of water is lost in terms of weight. It was unanimously determined that an increase in moisture brings about a decrease in the expansion ratio of the extrudates. In addition to that, adding leguminous plants into cereals mixture causes a slide reduction in the degree of expanding $S.E.I.$ for the mixture of wheat meal and lupine meal amounts to 1.03. That is result of oil content in the mixture. Similar effects has been observed with addition of soya meal.

2. The highest expantion ratio is noticeable in the structure building starchy materials. These are mostly maize grits $S.E.I.$ = 3.45 and extrudates obtained from the mixtures which contain maize grits, wheat flour, wheat grits and rice grits $S.E.I.$= 3.79.

3. The highest value of WAI was noted for the extrudates obtained from the mixtures of maize grits with wheat grain and wheat meal (WAI = 533.3%) and the mixture of wheat meal and wheat flour (WAI= 453.3%). In the case of mixtures which contain leguminous and/or oil

Table 2. *WAI* and expantion ratio of the extrudates obtained

No.	Raw materials	Composition (%)	*WAI* (%)	Standard deviation (δ)	Expantion ratio	Standard deviation (δ)
1.	Maize grits	100	218.3	0.40	3.45	0.11
2.	Maize grits	80	215.8	0.66	2.74	0.10
	Rape cake meal	20				
3.	Maize grits	80	175.0	0.54	2.11	0.05
	Wheat meal	10				
	Lupine meal	10				
4.	Maize grits	50	113.3	0.51	1.33	0.07
	Lupine meal	50				
5.	Maize grits	50	210.0	0.00	2.77	0.05
	Rye meal	50				
6.	Maize grits	50	204.2	0.37	3.10	0.08
	Wheat grits	50				
7.	Maize grits	60	312.5	1.54	2.82	0.04
	Wheat meal	40				
8.	Maize grits	40	196.7	0.81	3.79	0.05
	Rice grits	20				
	Wheat flour	20				
	Wheat grits	20				
9.	Maize grits	30	533.3	0.51	3.04	0.05
	Wheat meal	50				
	Rye meal	20				
10.	Maize grits	20	431.7	0.40	2.89	0.04
	Wheat meal	60				
	Rye meal	10				
	Wheat flour	10				
11.	Maize grits	20	195.0	0.54	3.35	0.05
	Wheat grits	20				
	Wheat meal	20				
	Wheat flour	20				
	Rye meal	20				
12.	Maize grits	10	431.7	0.40	2.32	0.08
	Wheat meal	80				
	Rape cake	10				
13.	Wheat grains	100	303.3	0.60	2.54	0.04
14.	Rye grains	100	376.7	0.51	2.46	0.08
15.	Wheat grains	50	109.2	0.49	1.65	0.07
	Rye grains	50				
16.	Wheat grains	50	153.3	0.75	1.40	0.05
	Barley grains	50				
17.	Wheat meal	80	105.0	0.54	1.31	0.03
	Soya meal	20				
18.	Wheat meal	70	110.0	0.63	1.88	0.05
	Rape cake	30				
19.	Wheat meal	50	183.3	0.51	1.03	0.02
	Lupine meal	50				
20.	Wheat meal	50	193.3	0.51	2.35	0.05
	Potato starch	50				
21.	Wheat meal	50	351.7	0.75	2.16	0.09
	Broad beans meal	50				
22.	Barley meal	100	118.3	0.51	1.10	0.02
23.	Barley meal	80	200.0	0.31	1.10	0.02
	Rape seets meal	20				
24.	Barley meal	50	203.3	0.51	1.04	0.02
	White lupine meal	50				
25.	Soya meal	50	104.2	0.49	1.08	0.03
	Broad beans meal	50				

-plant ground seeds, water absorption index is very low: for the soya meal and broad beans mixture the value of *WAI* is 104.2% whereas for the mixture of wheat meal and rape cake it amounts to 110%. These values are attributed to the fact that while the protein contents in the mixtures increases, the water absorption capacity is reduced and the mixture becomes more crunchy. Therefore, to increase *WAI* the addition of starchy raw materials to the mixture can give positive results.

4. Further detailed study is needed to describe how chemical composition of the processed mixtures can influence the final physical properties of the extrudates. Analytical work has to focus on the mutual relations between the main components of raw materials used during extrusion-cooking and their role in structure building of the extrudates.

5. Three different size fraction of the processed material have a moderate influence on the *S.E.I.* and *WAI* values, especially in the case of extrusion cooking of multicomponent mixtures. Wider tests are needed to recognise detailed relations in this field. Mentioned fractions were too extensive to observe influence of particle size distribution on physical properties of the processed materials.

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