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THE EFFECT OF PLANT-MEAT BLENDS COMPOSITION AND EXTRUSION TEMPERATURE ON THE PHYSICAL PROPERTIES OF EXTRUDATES

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A b s t r a c t. The study was concerned with the effect of the percentage share of meat material, plant material and extrusion temperature on the process run and physical properties of extrudates. Meat-bone pulp (MBP) from mechanical de-boning of poultry carcasses, faba bean wholemeal, and barley grain meal were used in this study. The extrusion process was conducted using a twin-screw extruder with counter-rotating conical screws. It was demonstrated that the extruder used in this study permits the processing of blends with up to 25% meat-bone material content. The extrudates obtained were characterised by a loose, gritty-like granular form. Pellet durability index (PDI) of extrudates ranged from 60.30 to 96.24%. Increase in the content of MBP caused a decrease of PDI. Increase of the percentage share of MBP from 5 to 10% caused an increase of the water absorption index (WAI). However, no clear pattern was observed for WAI value as a result of increases in MBP above the 10% level. Likewise, no significant effect of MBP on the water solubility index (WSI) was noted. Extrusion temperature increase from 130 to 250°C caused an increase in PDI. Analysis of microstructure revealed a significant effect of process temperature on the structure of extrudates. At higher temperatures the formation of fibrous structures was observed, that might be responsible for increasing the PDI. Only slight, but statistically significant changes in the values of WSI and WAI, caused by process temperature change, were noted.

K e y w o r d s: feed quality, meat-bone pulp, extrusion, microstructure

INTRODUCTION

Until recently, one of the basic sources of high-value and easily assimilable proteins, in feed technologies, were meat and meat-bone meals. The appearance of bovine spongiform encephalopathy (BSE) caused the introduction of a number of legislative acts aimed at limitation of the use of that material for the production

of feeds. The Regulation of the European Parliament and Council (EC 2009) permits the possibility of utilisation of low quality meat materials such as meat-bone pulp (MBP) or meet waste materials (classified in the lowest – the third risk category**)** for the production of feeds, under the condition that they are processed into products with suitable microbiological purity. Extrusion cooking gives the ability to improve the microbiological quality of meat materials (Likimani and Sofos 1990, Okelo *et al*. 2006, Saalia and Phillips 2011).

Extrusion processing has become very popular in the feed industries due to high versatility, productivity, and product quality (Ayadi *et al.* 2013, Samuelsen *et al.* 2013). Specific properties of extrudates, e.g. porous structure, texture, expansion, specific density, pellet durability index (PDI), water absorption index (WAI) and water solubility index (WSI), can be created through the composition of the blend material and parameters of the extrusion process, such as extruder type, profile of barrel temperature and pressure distribution, configuration and speed of the extruder screws, size and shape of the die aperture (Ayadi *et al.* 2013, Samuelsen *et al.* 2013, Wang and Ryu 2013). However, despite increased use of extrusion, it is still a complicated process that has yet to be mastered.

A study was conducted to determine the possibility of utilising meat-bone pulp (MBP) for the production of feed components with the use of the technology of extrusion. The effect of cereal-meat blends composition on the possibility of stabilisation of extrusion conditions, physical properties of extrudates, and on their microstructure was determined.

MATERIAL AND METHOD

Meat-bone pulp (MBP) from mechanical de-boning of poultry carcasses (Indykpol S.A., Lublin, Poland), faba bean wholemeal (*Vicia faba* L.), and barley (*Hordeum vulgare* L.) grain meal (Agropol, Motycz, Poland) were used in this study. The chemical composition of raw materials is presented in Table 1. The plant materials were ground by means of a universal impact mill type H-111/3 (Agromet, Jawor, Poland), using sieve with mesh diameter of 3 mm.

The share of the meat-bone pulp was variable in the range of 5 to 25%. After all ingredients were thoroughly combined, each blend was adjusted to the desired moisture content of 28% by adding water. The MBP was mixed with the plant materials in a periodic mixer type H-095 (Agro-Wikt, Opoczno, Poland) with capacity of 80 dm^3. The study was conducted in three series, determining successively the effect of increasing share of MBP (samples 1-5), faba bean meal (samples 6-11), at constant barrel temperature profile, and of the process temperature (samples 12-18), at constant blend composition, on the physical properties and the chemical composition of the extrudates. The extrusion process was conducted

using a 2S-9/5 twin-screw extruder with counter-rotating conical screws (Metalchem Gliwice, Poland, L/D ratio of 12:1, die 3x6 mm, screw speed 75 rpm), and different barrel temperature profiles were used (Tab. 2).

Table 1. Chemical composition of raw materials (n = 3)

Nutrient	Meat-bone pulp	Barley	Faba bean
Dry matter (%)	43.10	87.75	89.80
Crude protein (g kg^{-1} d.m)	421.3	125.1	284.8
Crude fat (g kg^{-1} d.m)	182.5	23.2	13.0
Ash (g kg^{-1} d.m)	283.4	21.2	36.2
TDF (g kg^{-1} d.m)	–	270.1	344.8
IDF (g kg^{-1} d.m)	–	211.9	296.1
SDF (g kg^{-1} d.m)	–	58.2	48.7
N-free extr. (g kg^{-1} d.m.)	–	437.9	219.2

TDF – total dietary fibre, IDF – insoluble dietary fibre, SDF – soluble fibre

Table 2. Experimental design used in the study

Sample	Mixture composition (%)			Temperature profile (°C)
	Meat-bone pulp	Faba bean wholemeal	Barley wholemeal	
1	5	20	75	120/140/180/180/130
2	10	20	70	
3	15	20	65	
4	20	20	60	
5	25	20	55	
6	20	0	80	120/140/180/180/130
7	20	5	75	
8	20	10	70	
9	20	15	65	
10	20	20	60	
11	20	25	55	
12	20	20	60	90/110/130/130/130
13	20	20	60	110/130/150/150/130
14	20	20	60	120/140/170/170/130
15	20	20	60	125/150/190/190/130
16	20	20	60	130/160/210/210/130
17	20	20	60	140/170/230/230/130
18	20	20	60	150/180/250/250/130

After the prepared blends were cooked in the extruder and dried for 72 h at room temperature (25 ± 1°C), they were then analysed for physical properties.

Pellet durability index (PDI) was determined following Method S269.4 (ASAE 2004). Approximately 500 g of extrudates from each blend were manually

sieved for about 10 s to remove initial fines, and then tumbled in a pellet durability tester (Model PDT-110, Seedburo Equipment Company, Chicago IL, USA) for 10 min. Afterwards, the samples were again hand sieved for about 10 s, and then weighed on an electronic balance. PDI was calculated as:

$$PDI = (M_a \div M_b) \cdot 100 \qquad (\%) \tag{1}$$

where: M_a – mass (g) after tumbling, and M_b – sample mass (g) before tumbling.

Water absorption index (WAI) and water solubility index (WSI) were measured according to the centrifuge method 88-04 (AACC, 2000). Extrudate sample of each treatment combination were ground with a laboratory mill to an average particle size of about 500 μm. Approximately 2 g of the extrudate powder was suspended in 30 mL of distilled water (temp. 20°C), in a tarred 50 mL centrifuge tube, then stirred carefully and left for 5 min. Afterwards, the water-extrudate suspension was centrifuged for 15 min (RCF 10000 g) in a laboratory-scale centrifuge (MLW T24D, VEB MLW Medizintechnik, Germany). The supernatant was decanted into a weighing vessel and dried at 105°C until solid matter was obtained in the laboratory oven. The ratio of the remaining gel mass in the centrifuge tube to the dry matter of the original sample mass was used to determine the water absorption index:

$$WAI = \left(W_g \div W_{dm}\right) \cdot 100 \qquad (\%\ \mathrm{d.w.}) \tag{2}$$

where: W_g – gel weight (g), and W_{dm} – dry matter of the original sample mass (g).

The value of WSI was determined from the formula:

$$WSI = (W_{ds} \div W_{dm}) \cdot 100 \qquad (\%\ \mathrm{d.w.}) \tag{3}$$

where: W_{ds} – dry matter of supernatant residue (g), and W_{dm} – dry matter of the original sample mass (g).

Moisture content was determined with the method 44-15A (AACC, 2000). The gravity-convection oven type Sup-4 (Wamed, Warszawa, Poland) was used. Ash content was assayed according to the method 08-01, protein content (N x 6.25) with the method 46-08 (AACC, 2000). For protein content analysis the KjeltecTM 2300 Automatic Analyzer (Foss, Hoganas, Sweden) was used. Free fat was determined in accordance with the method 30-26 (AACC, 2000) by means of SoxtecTM 2050 (Foss, Hoganas, Sweden). Enzymatic method was applied to determine the content of total dietary fibre (TDF), soluble dietary fibre (SDF) and insoluble dietary fibre (IDF). Megazyme enzymes and methodological procedures were employed: AOAC 991.43, AACC 32-07, AACC 32-21, AOAC 985.29, AACC 32-05 (AACC, 2000; AOAC, 1990). From the difference of dry matter and the above, N-free extract was calculated.

Selected samples were used to slice off fragments of extrudates that were then glued with silver paste onto specimen circles and sprayed with carbon and gold in a vacuum sprayer type JOEL JEE 4X (JEOL, Tokyo, Japan). Microscope analyses were made with the help of electron microscope type JSM 5200 (JEOL, Tokyo, Japan), using accelerating voltage of 10 kV.

Each blend was extruded once. For each treatment combination, five replicates (n = 5) for all physical properties and three replicates (n = 3) for all chemical analyses were determined. All collected data were analysed with SAS v.9.1.3 (SAS Institute Inc., Cary, NC). One-factor analysis of variance was performed based on the Duncan test, adopting significance level $\alpha = 0.05$. The Pearson coefficients of linear correlation between chemical composition of blends and physical properties of extrudates were also determined.

RESULTS AND DISCUSSION

The parameter ranges applied in the study and the composition of the blends were determined on the basis of pilot experiments. Only such parameters were adopted that guaranteed correct and stable run of the process (Tab. 2). Material moisture of 28% and share of meat-bone pulp (MBP) up to 25% permitted the process of "dry" extrusion (the material was particulate). The extrudates produced were characterised by a loose, gritty-like form, permitting their utilisation as a component of feed blends. Higher content of MBP (> 25%) caused an excessive moisture of the material, which led to the material sticking to the feeder screws and the extruder screws. The disturbances observed in material dosage caused non-uniform flow of the mass in the extruder cylinder. That resulted in the material caking on the cylinder walls and on the screws, and blocking the extruder. According to Rockey (1994), the optimum moisture level for processing is 25-30%; lower moisture levels during processing contribute to the destruction of heat-labile nutrients such as lysine and ascorbic acid.

PDI is typically used to assess extrudates' ability to withstand destructive external forces during transportation, storage and feed delivery system (Ayadi *et al.* 2013, Samuelsen *et al.* 2013). However, in the case of extrudates used as a feed component, too high a mechanical strength may cause problems with achieving an adequate degree of fragmentation that would ensure correct mixing of the blend components. PDI ranged from 60.30 to 96.24% (Tab. 3). Changes in the percentage share of MBP and the process temperature had the strongest effect on the PDI. Increase in the share of MBP caused a significant decrease (Duncan test, $P \leq 0.05$) in the value of PDI (samples 1-5). At 5% share of MBP the durability index was 96.24%, while at 25% share of MBP the durability index decreased to

73.80%. Increase of the process temperature, at constant blend composition (samples 12-18), caused a significant increase of PDI, from 70 to 85% (Tab. 3).

Table 3. Physical properties of the extrudates (n = 5)

Sample	PDI	WSI	WAI
	(%)	(% d.m.)	(% d.m.)
1	96.2 a ± 1.1	6.52 dc ± 0.2	315.3 e ± 3.1
2	89.7 b ± 0.1	6.9 ba ± 0.12	355.6 b ± 3.3
3	84.6 c ± 0.5	6.99 ba ± 0.12	343.2 c ± 2.7
4	75 egf ± 1.2	6.97 ba ± 0.05	356.9 b ± 2.7
5	73.8 ghf ± 1.7	7.04 a ± 0.11	346.6 c ± 2.7
6	73.1 gh ± 1.1	5.08 g ± 0.13	307.6 f ± 2.2
7	75.9 edf ± 1.3	6.04 e ± 0.24	288.4 hij ± 2.3
8	75.2 egdf ± 0.9	6.52 dc ± 0.22	285.3 ij ± 4.8
9	77.2 ed ± 2.1	6.87 ba ± 0.19	294.6 hg ± 2.6
10	78.2 d ± 1.9	6.75 bdc ± 0.22	277.7 k ± 3.5
11	77.6 ed ± 2.1	6.55 dc ± 0.24	284.7 j ± 2.7
12	70 i ± 2.1	6.71 bdc ± 0.11	409.3 a ± 3
13	72.7 igh ± 1.9	6.99 ba ± 0.02	291.6 hi ± 3.8
14	60.3 k ± 2	6.54 dc ± 0.05	300.7 g ± 4.5
15	64.4 j ± 1.5	6.48 d ± 0.09	288.3 hij ± 5.9
16	70.8 ih ± 2.2	6.78 bac ± 0.03	306.5 f ± 3.7
17	76.2 edf ± 2.4	6.23 e ± 0.2	300.3 g ± 3.7
18	85 c ± 2	5.57 f ± 0.09	336.2 d ± 3.9

PDI – Pellet durability index; WSI – water solubility index; WAI – Water absorption index, Means within a column marked with different letters differ at $P \leq 0.05$

A negative correlation was noted between the content of animal proteins in the blends and the PDI (–0.966), and between the content of animal fat and the PDI (–0.978) (Tab. 4). The results could be attributed to the increase in fat and the concomitant decrease in starch content in the raw ingredient blends with an increase in MBP level. These compositional changes can reduce the friction between the feed and the die during processing, lowering the degree of processing of the material. A negative effect of fat on the value of PDI is also supported by studies conducted by Briggs *et al.* (1999). A significant effect of animal protein on PDI was demonstrated in studies by Ayadi *et al.* (2012) and Samuelsen *et al.* (2013). However, those authors noted positive correlations between the content of animal protein and the value of PDI. According to Ayadi *et al.* (2012) it is not always possible to demonstrate a direct relationship between the content of animal protein and PDI. The value of PDI is strongly influenced not only by the content of protein, but also by its solubility, and especially by the share of small water soluble peptides and amino acids. A high level of non-soluble proteins in the feed

mix may result in a low degree of cooking in the extruder barrel, i.e., increased level of solid particles in the extrudate with resulting poor pellet hardness and durability (Samuelsen *et al.* 2013). The negative effect of MBP on PDI observed in our study might be attributed to the lack of an efficient plasticiser in the feed mass. Another cause for a decrease in the value of PDI can be a reduction of the share of starch with simultaneous limitation of the degree of its gelatinisation in the course of the process.

Table 4. Linear correlation coefficients between extrudate properties and chemical composition of raw blends

Parameters	PDI	WSI	WAI
N-free extr.	0.834*, p < 0.001	0.125, p < 0.713	–0.227, p < 0.502
Total protein	–0.605*, p = 0.049	–0.003, p = 0.993	0.489, p = 0.127
Vegetable protein	0.767*, p = 0.006	0.359, p = 0.279	0.687*, p = 0.02
Animal protein	–0.966*, p < 0.0001	–0.237, p = 0.483	–0.074, p = 0.829
Total fat	–0.978*, p < 0.0001	–0.258, p = 0.443	–0.143, p = 0.676
Vegetable fat	0.691*, p = 0.019	0.045, p = 0.897	–0.406, p = 0.215
Animal fat	–0.966*, p < 0.0001	–0.237, p = 0.483	–0.074, p = 0.829
TDF	0.977*, p < 0.0001	0.31, p = 0.353	0.336, p = 0.313
SDF	0.899*, p = 0	0.171, p = 0.616	–0.113, p = 0.74
IDF	0.957*, p < 0.0001	0.329, p = 0.324	0.419, p = 0.199
Ash	–0.948*, p < 0.0001	–0.215, p = 0.525	–0.01, p = 0.978

TDF – total dietary fibre; SDF – soluble dietary fibre; IDF – insoluble dietary fibre; PDI – pellet durability index, WAI – water absorption index, WSI – water solubility index, * – correlation coefficient statistically significant ($P \leq 0.05$)

Changes in the proportions of the content of the plant components (samples 6-11), at a constant 20% addition of MBP, did not cause any big changes in the values of PDI which fell within the range of 73.1-78.2% (Tab. 3). Increase of faba bean meal (FBM) (samples 6-11) in the blends, like the increase of the share of MBP earlier, leads to an increase in the content of total proteins in the blends. In this case, as opposed to samples 1-5, there is a simultaneous decrease of the content of fat. In turn, higher share of barley meal (BM) was related with simultaneously higher content of fat and starch in the blends. This fact may explain the observed positive correlation between the content of vegetable fat in the blends and the value of PDI (Tab. 4).

Higher process temperature causes that starch contained in the raw materials gets gelatinised to a greater degree and the product obtained has a higher kinematic strength. The relatively wide range of changes of PDI indicates a possibility of creation of that property of extrudates by means of the process temperature.

Increase MBP in the blends (samples 1-5) caused changes in the values of WAI, however, no clear pattern was observed (Tab. 3). Increase of the share of MBP from 5 to 10%, caused a significant increase of WAI, but further increase of the share of MBP, above 10%, did not lead to such notable changes in the WAI. At 5% share of MBP the value of WAI was 315.3% d.w., while at 25% content of MBP the value of WAI increased to 346.6% d.w. The values of WSI for these extrudates ranged between 6.52. and 7.04% d.w. The observed differences between WSI values were not statistically significant (Duncan, $p \leq 0.05$), except for the blend containing 5% MBP which had the lowest WSI value (6.52% d.w.).

In samples with 20% share of MBP (samples 6-7), WSI fell within the range of 5.08-6.87% d.w., while WAI in the range from 277.7 to 307.6% d.w. (Tab. 3). Changes in WSI and WAI were statistically significant (Duncan, $P \leq 0.05$). However, from our results, no clear effects on the WAI and WSI due to changes in the ratio of plant components were found. Initial increase of the share of faba bean meal caused an increase of WSI with simultaneous decrease of WAI, but after exceeding the level of 15% the relation was reversed.

Analysis of changes of WSI and WAI is frequently used as a simple indicator of process intensity (Yağci and Göğüş 2008). Both the small range of changes of WAI and WSI and the relatively low values of WSI suggest a slight degree of degradation of the product and indicate a low susceptibility of the product to dissolution (Tab. 3). The low values of WSI may be caused by high fat content in the extruded blends. Fat could have caused a lubricating effect and thus decrease the shear rate gradient. Reduced friction slowed down the depolymerisation of starch. Increase in fat content also intensifies the formation of insoluble starch-lipid complexes, which can also be a cause of low WSI values of products (Van Hoan *et al.* 2010). However, in the presented study no high correlations were noted between fat content in the blends and WSI, and between fat content and WAI (Tab. 4). It appears that in this case fundamental importance should be attributed to the fact that increasing share of MBP was related with a lower level of high-starch plant components (FBM, BM). Decrease in the content of starch in the extruded material could have been a cause of these results.

WSI of extrudates decreased slightly with increase of process temperature (Tab. 3). At process temperature of 130°C (4th zone temperature) the value of WSI was 6.71% d.w, while after temperature increase to 250°C the value of WSI decreased to 5.57% d.w. The small range of changes of WSI with changing process temperature suggests a limited influence of temperature on product degradation. This is a non-typical behaviour; most frequently an increase of the value of WSI with temperature increase is observed. A high content of fat in the blends, leading to a decrease of friction between the feed and the die during processing, limits the degree of dextrinisation of starch. It is also possible that insoluble

starch-fat complexes formed during the process contribute to the low values of WSI. The changes of the values of WAI provide confirmation of changes in the intensity of the process determined in the basis of WSI (Tab. 3). The range of changes of WSI and WAI, resulting from increase of the process temperature, indicates a possibility of obtaining a sterile product with simultaneous limitation of its degradation.

Analysis of microstructure was conducted for selected extrudates with 20% share of MBP (samples 4, 6, 12, 24). Figure 1 (a-c) presents extrudates with 80% share of barley meal (sample 6). Figure 2 (1a-c) presents the microstructure of extrudates with 20% addition of FBM and BM (sample 4). Figure 2 (1a-c, 2a-c, 3a-c) also presents a comparison of the structure of extrudates produced at temperatures of 130, 180 and 250°C (4th section temperature).

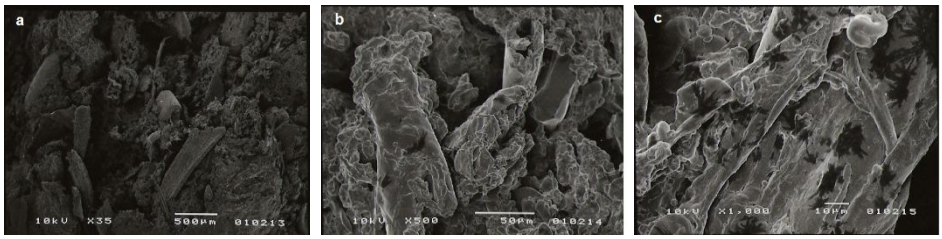

Fig. 1. Scanning electron micrographs of extrudates. Raw composition: 20% meat-bone pulp and 80% barley meal; barrel temperature profile: 120/140/180/180/130°C. Magnification: a) x35; b) x500; c) x1000

The process of extrusion, in our work, caused physical and chemical transformations of the material processed. The consequence of those transformations was a change in the structure of the material. The high share of BM in extrudates caused an increase in the share of dietary fibre with fibrous structure. Those extrudates were characterised by low values of WSI (Tab. 3), which could suggest an insufficient level of processing. Magnification x35 shows a loose, gritty-like structure (Fig. 1a-c, sample 6). One can observe small non-liquefied fragments of bone and barley husks. Further magnifications, x500 and x1000, indicate good processing of the raw material (Fig. 1 b-c), as the non-liquefied fragments are encased in moulded starch-protein mass, forming the skeleton of the extrudate. However, such a structure does not ensure high mechanical strength of extrudate; DPI of those extrudates was 73.1%.

Figure 2 (1a-c) presents the changes of microstructure of extrudates resulting from the application of 20% addition of FBM (sample 4) instead of BM. The value of WSI of those extrudates, compared to extrudates with 80% share of barley meal, is higher (Tab. 3). Analysis of the photos indicates a high degree of processing of

the raw material. The visible non-liquefied elements are less numerous (x35) and, as in the case of sample 6, encased in liquefied mass observable at magnification x500. The visible spherical structures are the remnants of starch granules from which gelatinised starch oozed out. Additionally, they are encased in a thin layer of molten protein mass and connected with thin bridges into a slightly fibrous structure (x500, x1000). However, the observed changes in the microstructure of the extrudates did not cause any significant changes (Duncan, $P \leq 0.05$) in the value of DPI (Tab. 3). Similar starch structures are formed also in the case of other legume materials, e.g. everlasting pea (Rzedzicki and Fornal 1999).

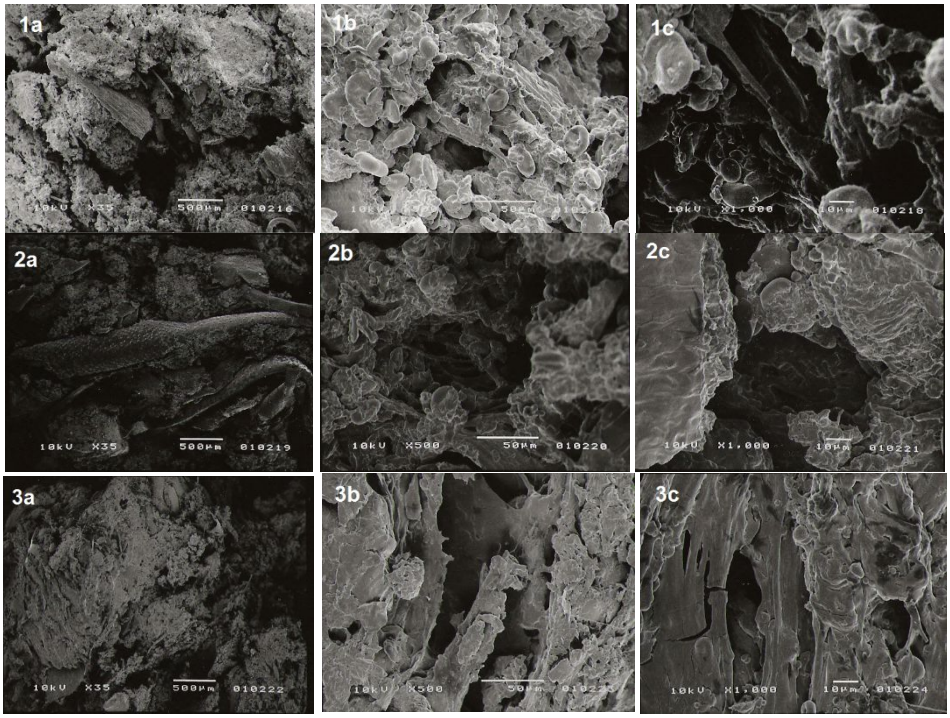

Fig. 2. Scanning electron micrographs of extrudates. Raw composition: 20% meat-bone pulp, 20% faba bean meal and 60% barley meal. Magnification: a) x35; b) x500; c) x1000. Barrel temperature profile: 1) 120/140/180/180/130°C, 2) 90/110/130/130/130°C, 3) 150/180/250/250/130°C

The study demonstrated a very strong effect of extrusion temperature on the internal structure of the product. Application of low process temperatures (130°C) resulted in the appearance of cohesive and compacted, gritty-like structure. Photographs of microstructure reveal non-liquefied fragments of raw material and starch granules. Most probably, under conditions of low extrusion temperature

and the protective action of fat, starch was not completely gelatinised. Increase of extrusion temperature caused a clearly visible change in the microstructure of the products. The gritty-like microstructure observed earlier, disappeared. The extrudates obtained had a characteristic fibrous structure, not observed in the case of extrudates produced at temperature of 130°C. At magnification x500 one can clearly see homogeneous cell walls and air spaces with sizes of as much as tens of micrometres. The visible individual large air cells are limited with thick walls. As demonstrated earlier, increase of process temperature from 130 to 250°C caused a significant increase of DPI of the extrudates (Tab. 3). Analysis of microstructure indicates that the changes of DPI may be due to the formation of fibrous structure, displaying an increased resistance to the effect of external forces.

CONCLUSION

1. The "dry" extrusion of blends with a content of meat-bone pulp proceeded correctly within a broad range of parameters. The combination of raw materials of plant origin (faba bean, barley) and animal origin (MBP), at the adopted process parameters (blend moisture, process temperature), permitted the obtainment of gritty-like form of extrudates which can find an application as feed mix components.

2. Increase in the share of MBP in the extruded blends caused a significant decrease of PDI of extrudates, while increased levels of FBM resulted in a slight increase of PDI. These relations may result from simultaneous changes in the content of fat and starch in the blends, caused by the changes in the shares of those components. Increase in the content of fat and decrease in that of starch cause a decrease in the value of PDI. No significant changes were noted in the values of WSI and WAI of extrudates with increase in the share of MBP in the blends above the level of 10%.

3. In the case of blends with constant 20% share of MBP, an increase in extrusion temperature had a significant effect on the values of PDI. An increase of PDI was noted with increasing process temperature. Whereas, the application of higher process temperatures did not cause any significant changes in the values of WSI and WAI of extrudates. This indicates a limited degree of degradation of the product, probably related with increased content of fat in the blends.

4. The thermoplastic treatment of the raw materials used in the study, conducted at various temperatures, resulted in the obtainment of products with varied microstructure. Analysis of the photographs confirmed the high level of processing of the raw material; non-liquefied fragments of raw material occurred in small amounts, especially in extrudates produced at lower temperatures (130°C). Increase of the process temperature caused also the formation of fibrous structures which could be responsible for increased values of PDI.

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WPŁYW SKŁADU SUROWCOWEGO MIESZANEK ROŚLINNO-MIĘSNYCH I TEMPERATURY EKSTRUZJI NA WŁASCIWOŚCI FIZYCZNE EKSTRUDATÓW

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S t r e s z c z e n i e. Celem przeprowadzonych badań było określenie wpływu udziału surowca mięsnego w połączeniu z surowcami roślinnymi oraz temperatury ekstruzji na przebieg procesu oraz właściwości fizyczne ekstrudatów. W badaniach wykorzystano miazgę mięsno-kostną (MBP) pochodzącą z mechanicznego odkostniania tuszek drobiowych oraz razówkę bobikową i jęczmienną. Ekstruzję przeprowadzono z wykorzystaniem przeciwbieżnego ekstrudera dwuślimakowego. Wykazano możliwość przetwarzania mieszanek z udziałem miazgi mięsno kostnej dochodzącym do 25%. Uzyskane ekstrudaty charakteryzowały się luźną, kaszkowatą formą. Wskaźnik wytrzymałości kinetycznej (PDI) ekstrudatów mieścił się w zakresie od 60,30 do 96,24%. Zwiększenie udziału MBP w mieszankach powodowało obniżenie wytrzymałości kinetycznej ekstrudatów. Wzrost udziału MBP w mieszankach, z 5 do 10%, spowodował zwiększenie wodochłonności ekstrudatu (WAI). Nie odnotowano jednoznacznego wpływu MBP, przy jej udziale w mieszance powyżej 10%, na wartość WAI ekstrudatów. Nie wykazano, także istotnych zależności pomiędzy zawartością MBP a współczynnikiem rozpuszczalności suchej masy (WSI) ekstrudatów. Wzrost temperatury ekstruzji ze 130 do 250°C spowodował wzrost PDI. Analiza mikrostruktury wykazała istotny wpływ temperatury procesu na strukturę ekstrudatów, obserwowano m. in powstawanie struktur włóknistych w wyższych temp. procesu, mogących odpowiadać za zwiększenie wartości PDI ekstrudatów. Odnotowano nieznaczne, statystycznie istotne (Duncan, $p \leq 0,05$), zmiany wartości WSI i WAI wywołane zmianą temp. procesu.

S ł o w a k l u c z o w e: karma, jakość, miazga mięsno-kostna, ekstruzja, mikrostruktura