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Effect of the extrusion process of corn semolina and pea hulls blends on chemical composition and selected physical properties of the extrudate

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A b s t r a c t. A study was conducted on the process of extrusion of blends of corn semolina and pea hulls to determine the effect of the share of high-fibre material and of parameters of the process of extrusion *eg* extruder barrel temperature and material moisture content, on the solubility of dry matter, viscosity, and content of fundamental chemical components – proteins, fats, and dietary fibre in the extrudates. Detailed analysis were performed for changes taking place in the dietary fibre fractions. Also analyzed were changes in the content of total dietary fibre as determined with the enzymatic method, including the fractions of soluble dietary fibre and insoluble dietary fibre. The study showed that extrusion cooking leads to a reduction in the content of crude fibre and free fats, and to a slight reduction in the level of proteins in the processed material. No significant changes were observed in the content of ash. Extrusion cooking resulted in decreased content of neutral-detergent fibre, acid-detergent fibre and cellulose fractions; at the same time a reduction was observed in the content of insoluble dietary fibre and an increase in the content of soluble dietary fibre fractions. It was found that intensive parameters of the process of extrusion (low moisture content of material and high process temperature) resulted in increased water solubility index values for the extrudates. The highest viscosity (after heating and cooling of suspension to 20°C) was characteristic of products obtained with the application of process temperature of 125°C.

K e y w o r d s: extrusion-cooking, pea hulls, cereals, dietary fibre, viscosity

INTRODUCTION

The world market is dominated by cereal snacks produced solely on the basis of high-starch materials such as corn semolina or rice. In the process of corn semolina production (in the hulling process) not only the hulls but also the germs are removed from corn grain. The product obtained in such technology, poor in proteins and in dietary fibre, is a base material commonly used in the technology of extrusion cooking where, under the combined effect of high temperature, high pressure (even up to 20 MPa) and intensive action of shearing forces, not only changes occur in the physical properties of the extruded mass, but also intense chemical transformations. The water solubility index (WSI) of extruded products can be even several-fold higher with relation to the raw material and oscillates around the level of 40-50% (Rzedzicki, 2005). Starch contained in the products undergoes gruelling and thus becomes available to digestive enzymes. As a result of such intense transformation, extruded starch products are characterized by high glycaemic index values (GI). Foster-Powell *et al.* (2002) report that average GI value of extruded corn flakes is 81. This assumes a special significance at the time of rapid increase in the incidence of Type 2 diabetes or the pandemia of obesity. It should be emphasized that the problem concerns also children and teenagers (Gahagan, 2004).

One of the possibilities of formation of pro-health features of extrudates and of lowering their energy density is their enrichment with high-fibre admixtures. So far, the most commonly used sources of dietary fibre in extruded products were cereal materials *eg* wheat or oat bran (Gualberto *et al.*, 1997; Onwulata *et al.*, 2001; Yanniotis *et al.*, 2007). Extrudates enriched with dietary fibre were characterized by notably lower WSI values (Onwulata *et al.*, 2001; Rzedzicki *et al.*, 2004b).

High-fibre components (oat or wheat bran) added to corn semolina caused also an increase in the viscosity of water suspensions of extrudates (Rzedzicki *et al.*, 2004c; Rzedzicki and Zarzycki, 2004). The viscosity of food products is highly important in the aspect of the process of digestion and absorption of nutrients in the alimentary tract. Numerous authors stress that soluble fibre fractions, for-

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ming high viscosity gels in the alimentary tract, slow down the hydrolysis and absorption of nutrients (Guillon and Champ, 2000; Schneeman, 2001; Burton-Freeman, 2000; Mathers and Daly, 2001). Dikeman and Fahey (2006) maintain that soluble fibre fractions (gums, pectins and β-glucans), causing an increase in the viscosity of gastric and intestinal contents, play a special role by lowering the after-meal concentration of glucose in the blood, and reduce the level of cholesterol.

Researchers indicate also the special role of the water solubility index (WSI) of extruded products. Choundhury and Guatam (1998), Onwulata *et al.* (2001), Singh and Smith (1997) maintain that WSI may be a specific measure of the degree of transformation of material. The authors point out the close relation between the intensity of the process and the degree of degradation of molecular mass of starch biopolymers, affecting the WSI value of extrudates.

The objective of the study presented here was determination of the possibility of application of pea hulls (a waste material in the process of pea hulling) for the production of snack-type expanded food products. The study was concerned with the effect of the content of the high-fibre material and of the parameters of the process of extrusion cooking – extruder barrel temperature distribution profile and material moisture content – on changes in the chemical composition of the material processed, with special emphasis on changes in dietary fibre and its fractional composition. Analysis was made of changes in viscosity and WSI values of extrudates, as functions of the content of high-fibre material and of variable parameters of the process of extrusion.

MATERIALS AND METHODS

The basic structure-forming material used in the study was commercially available corn semolina. The sources of dietary fibre were pea hulls cv. Opal and oat bran from the process of grinding of hulled oat grain. The basic chemical composition of the raw materials used in the study, the fractional composition of detergent fibre and fractional composition of enzymatic fibre are presented in Table 1.

The main variable factor in the experiment was the share of pea hulls that varied within the range of 2.5-15%. In a part of the model of the experiment an admixture of oat bran was applied, at the level of 3.5 and 5%, and of powdered whole milk at the rate of 0.5% (Table 1). The materials were moistened, homogenized and conditioned for 12 h at room temperature. The process of extrusion cooking was performed using an S-45 single-screw extrusion-cooker made by Metalchem Gliwice, with a screw of 3:1 compression ratio and an extrusion die of 3 mm in diameter. The variable parameters of the process included also the profile of temperature distribution in the extrusion-cooker barrel (varying within the range of 110/125/125 – 160/175/125°C) and material moisture level within the range of 13.5-16.5%.

T a b l e 1. Chemical compositions, detergent fiber fractions, TDF, IDF, and SDF dietary fiber of the raw materials

Parameters (% d.m.)	Raw material		
	Corn semolina	Pea hulls	Oat bran
Chemical composition			
N-free extract	86.01	44.53	68.68
Protein N x 6.25	11.11	15.55	16.96
Fat	1.01	1.75	7.94
Crude fiber	0.45	33.39	2.88
Ash	1.32	4.78	3.54
Detergent fiber fractions			
NDF	3.62	49.90	18.11
ADF	0.83	41.18	3.37
HCEL	2.79	8.72	14.74
CEL	0.66	40.75	1.48
ADL	0.17	0.43	1.89
Total, insoluble and soluble dietary fiber			
TDF	6.25	67.65	23.69
IDF	5.26	61.84	13.92
SDF	0.99	5.81	9.77

The water solubility index (WSI) was determined with the centrifuge method, applying parameters conforming to the AACC Method 56-20. Determination of viscosity was made in accordance with the method developed by Rzedzicki *et al.* (2004c). For the measurements, 5% water suspension of fragmented extrudates was prepared. Viscosity of the suspension was tested during heating within the temperature range of 20-90°C, and during cooling within the range of 90-20°C. Measurements of viscosity were taken at 10°C intervals. During the heating and cooling of the suspension a constant temperature gradient of 1°C min^{-1} was maintained. Measurements of viscosity were taken by means of a Mettler Rheomat RM180 rotary rheometer with coaxial cylinders. The measurement system No. 11 was used, with constant shear rate of 1200 s^{-1} and time interval of 10 s.

The raw materials and the produced extrudates were subjected to chemical composition analysis. The determinations included the total protein content (AACC, Method 46-08), crude fat content (AACC, Method 30-10), ash content (AACC, Method 08-01), crude fibre content (AACC, Method 32-10). Detergent fibre fractions were determined following the method of Van Soest (1963a,b). According to that method, the determinations included the content of fractions: neutral-detergent fibre (NDF), acid-detergent fibre (ADF), hemicellulose (HCEL), cellulose (CEL), and acid-detergent lignin (ADL). Total dietary fibre (TDF), insoluble fibre fraction (IDF) and soluble dietary fibre (SDF) were determined following methods AACC 32-05, AACC 32-21, AOAC 991.43, AACC 32-21, AOAC 985.29, with the use of Megazyme enzymes and procedures. The correctness of dietary fibre determinations was verified with the help of the Megazyme 'TDF control kit'. Chemical analyses were made in three replications. Values of WSI were determined in five replications. Calculations were made for mean values, standard deviation, and coefficient of variation. For continuous variables, regression equations were determined, as well as the coefficient of determination R^2. Statistical analysis of results was performed using SAS 9.1.3. and Excel software.

RESULTS AND DISCUSSION

The process of extrusion of blends of corn semolina and pea hulls at the level of 2.5-15% ran highly correctly. Attempts at increasing the content of pea hulls in the blend caused slippage of the material in the extruder, destabilization of the process, and – as a result – interruption of the process.

As a result of the process of extrusion, a 2.5- to 3-fold increase was observed in the water solubility index values. WSI values of the raw materials fell within the range of 5-6%, while those of extrudates produced from the materials were in the range of 15-16% (Fig. 1). The relatively high increase in the WSI values indicates a high degree of transformation of the material and a notable level of degradation of the molecular mass of starch polymers. The values of WSI recorded in this study were relatively very low. In extruded products of the breakfast cereals type available on the market the values of WSI reached even 50% (Rzedzicki, 2005). With increasing level of pea hulls in the extrudates, a slight decrease was noted in the WSI values of the products (Fig. 1). The direction of changes obtained in the study is in conformance with the results of other research (Onwulata *et al.*, 2001; Rzedzicki *et al.*, 2004b).

The WSI values of the products were also affected by the variable parameters of the process of extrusion cooking. Material moisture increase within the range of 13.5-16.5% caused a decrease in the WSI values of extrudates from 19.24 to 14.34% (Fig. 2). Changes in the WSI values observed under the effect of increase in the process temperature were less pronounced. Temperature increase from 125 to 175ºC resulted in extrudate WSI increase from 18.01 to 19.43% (Fig. 3).

Extrusion parameters affect also the viscosity of extrudates. Analysis of changes in viscosity in relation to the process temperature (Fig. 4) showed that the lowest viscosity at the phase of suspension heating was characteristic of extrudates obtained at process temperature of 125ºC. At the same time, those products were characterized by the highest viscosity in the phase of cooling. That results indicated, that such a low process temperature did not permit for total gruelling of starch. The process of starch gruelling intensified as a result of suspension heating to 90ºC during the viscosity measurements, hence those products were characterized by the highest viscosity in the cooling phase. Similar tendenies were recorded by Rzedzicki and Zarzycki (2004) and by Rzedzicki *et al.* (2004c) in their study on the viscosity of extrudates with a content of high-fibre wheat and oat components. Increase of extrusion temperature from 145 to 175ºC had no significant effect on changes in the viscosity of extrudates. The curves of viscosity in the function of heating and cooling have very similar shapes (Fig. 4). A different effect of extrusion temperature on the viscosity of water

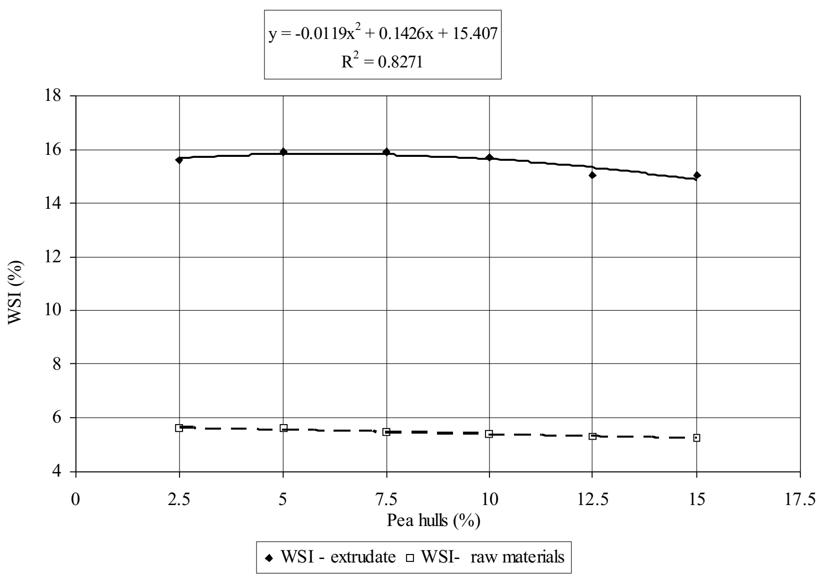

Fig. 1. Influence of the addition of pea hulls on the water solubility index (WSI) of the extrudate and raw materials.

suspension of potato starch is presented by Śmietana *et al.* (1996). According to those authors, extrusion temperature increase from 90 to 210ºC caused a lowering in the viscosity of extrudate suspensions measured at 20ºC.

The study showed that the parameter affecting the viscosity of extrudates was the moisture content of raw material (Fig. 5). The lowest viscosity of suspensions in the phases of heating and cooling was characteristic of samples obtained at the lowest raw material moisture level – 13.5%. Increase in raw material moisture content caused an increase in the viscosity of extrudates. Analysing changes in both WSI values and in viscosity of extrudates in the function of increasing moisture content of raw material, we can assume that increase in the moisture content of processed material causes, as reported by Colona *et al.* (1989), a decrease in dextrinization of starch and less intensive degradation of fibre structures. This would account for the higher viscosity of water suspensions of extrudates obtained from raw materials with higher moisture content.

Varying content of pea hulls in extrudates produced at temperature of 130/145/125ºC did not have any significant effect on changes in the viscosity of water suspensions of the

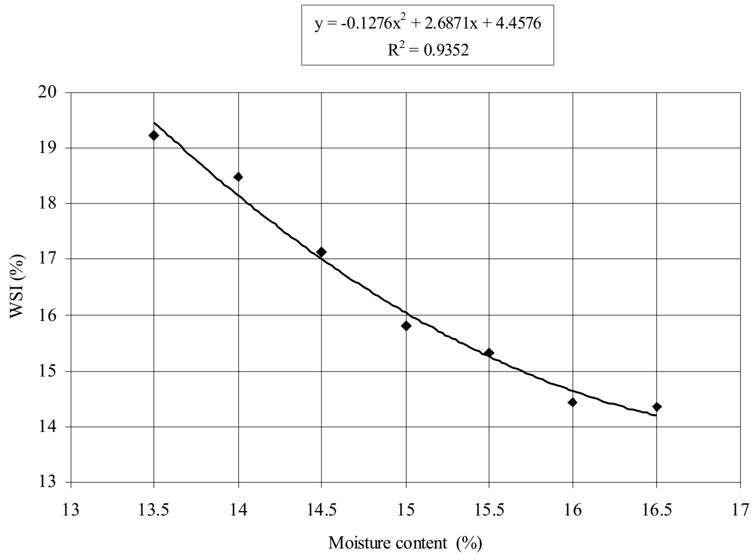

Fig. 2. Influence of moisture content of the raw materials on the WSI of the extrudate (pea hulls – 10% and corn semolina – 90%, temperature – 145°C).

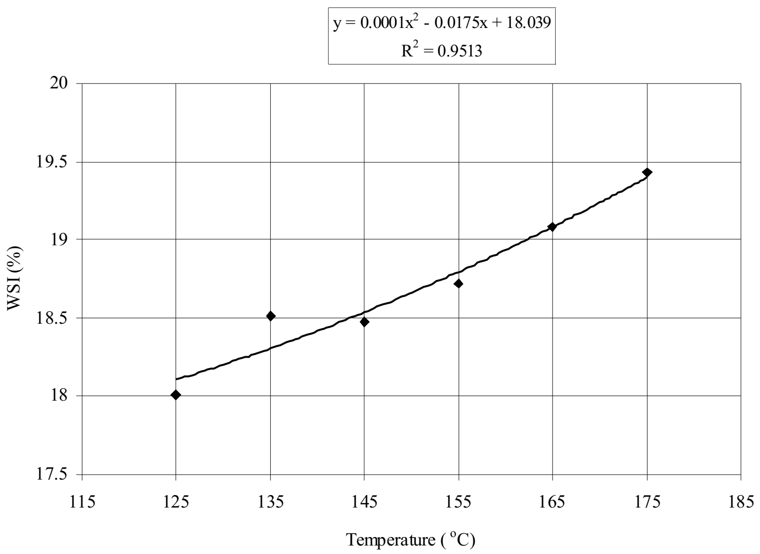

Fig. 3. Influence of barrel temperature on the WSI of the extrudate (pea hulls – 10% and corn semolina – 90%, moisture content – 14%).

extrudates (Fig. 6). It was observed that in all the samples analyzed the viscosity of suspensions of extrudates in the phase of cooling was only slightly higher compared to the viscosity of the suspensions in the phase of heating. This proves a high degree of transformation of the material and nearly total gruelling of starch during the extrusion.

Analysis of chemical composition of raw materials and extrudates produced showed that the process of extrusion cooking leads to significant changes in chemical composition. As a result of the process, a reduction is observed in the content of crude fibre and crude fat, and a slight reduction in the content of protein. No changes were observed in the ash content in the processed materials (Fig. 7).

The recorded changes in fat content (Table 2) result from its bonding in complexes by protein and starch in the course of the process (Singh *et al.*, 2007). This causes its reduced determinability through extraction with non-polar solvents. The non-polar solvent (hexane) used for extraction of fat permitted only the determination of so-called free fat. The difference between fat extracted from raw material and fat extracted from extrudates constitutes, according to Guzman *et al.* (1992), is a specific measure of fat bonding in the course of the process. The study showed that the degree of fat bonding in complexes is largely dependent on the process parameters applied – raw material moisture and extrusion temperature. With increase in the moisture content of the

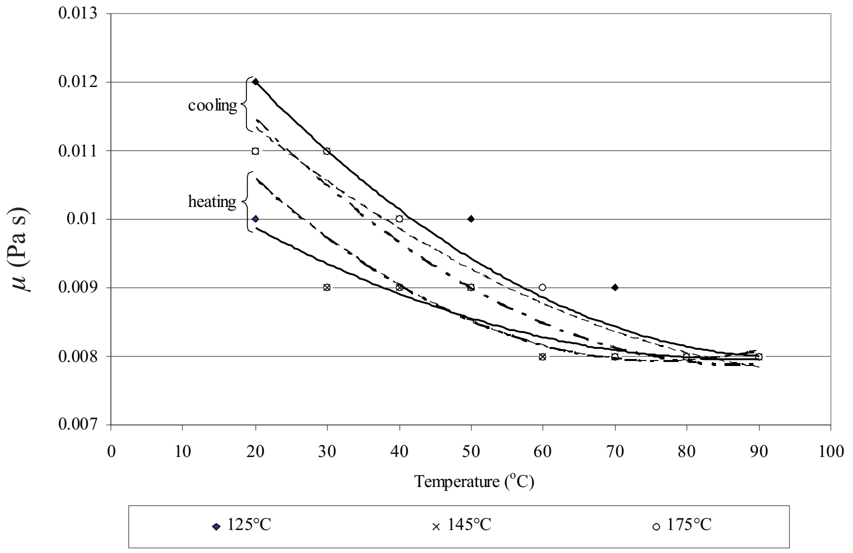

Fig. 4. Influence of barrel temperature on the dynamic viscosity. Samples contains pea hulls – 10% and corn semolina – 90%, moisture content – 14%.

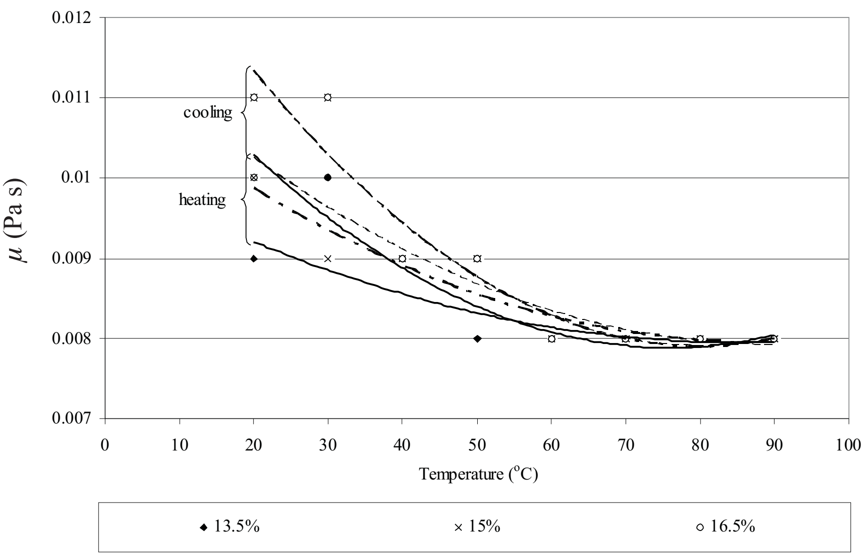

Fig. 5. Influence of moisture content of the raw materials on the dynamic viscosity. Samples contains pea hulls – 10% and corn semolina – 90%, temperature – 145°C.

processed blend from 13.5 to 16.5%, determinability of fat increased from 0.27 to 0.41%. Higher moisture content, therefore, resulted in decreased bonding of lipids in complexes in the course of the process. An inverse tendency was observed as a result of increase in extrusion temperature. Temperature increase from 125 to 175°C caused a reduction in fat determinability from 0.47 to 0.16%. The results obtained indicate that intensive parameters of the process of extrusion cooking of blends containing pea hulls (low moisture content and high temperature) are conducive to processes of lipid bonding in complexes. However, the study did not show any straightforward effect of the raw material composition of the blend on the degree of lipid bonding. For extrudates with 2.5-15% content of pea hulls the degree of fat bonding in complexes varied within the range of 66-77%.

The process of extrusion led to a lowering of the protein content in the processed material (Fig. 7). The recorded changes were small, but they applied to all the samples analyzed. A similar tendency was observed by, among others, Zieliński *et al.* (2001). Stanley (1989) stated that during the process of extrusion it is possible for isopeptide bonds to be formed between the ε-amine group of lysine and the amide group of asparagines or glutamine. The result of the reaction of amino acid condenzation is the emission of ammonia. In this way that author accounted for the slightly lower protein

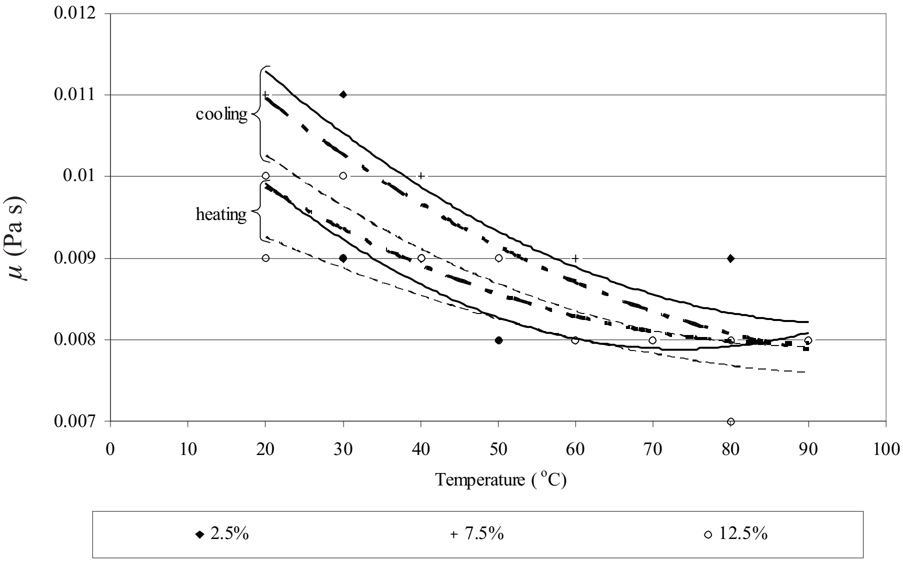

Fig. 6. Influence of pea hulls concentration on the dynamic viscosity. Samples contains oats bran – 5% and pea hulls – 2.5, 7.5, and 12.5%, respectively.

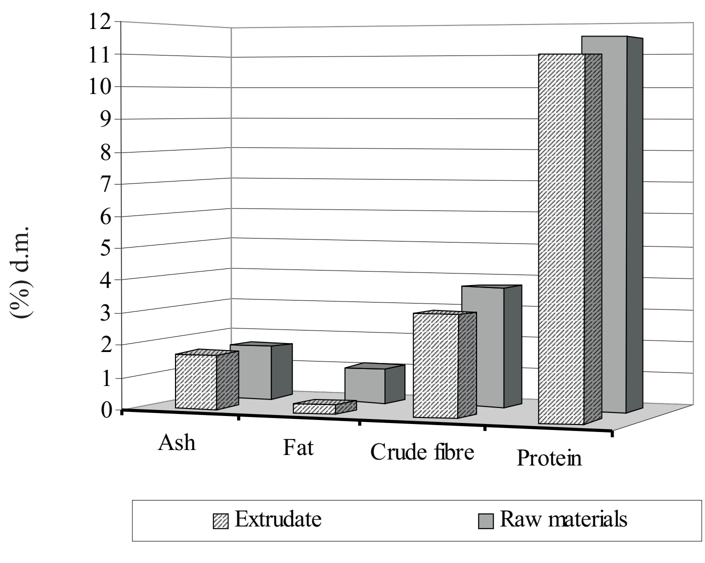

Fig. 7. Comparison of the chemical composition of raw material and extrudate (pea hulls – 10% and corn semolina – 90%, temperature – 145°C, moisture content – 13.5%).

T a b l e 2. Chemical composition of the extrudate

Component				Moisture (%)	Temperature (°C)	Protein Nx6.25	Fat	Free fat	Ash
Corn semolina	Pea hulls	Oat bran	Milk powder						
(%)							(% d.m.)		
94.0	2.5	3.5	0	13.37	130/145/125	8.64	1.27	0.38	1.43
91.5	5	3.5	0	13.35	130/145/125	8.32	1.30	0.37	1.52
89.0	7.5	3.5	0	13.31	130/145/125	8.71	1.31	0.44	1.61
86.5	10	3.5	0	13.29	130/145/125	8.51	1.33	0.33	1.67
84.0	12.5	3.5	0	13.26	130/145/125	9.06	1.34	0.34	1.78
81.5	15	3.5	0	13.23	130/145/125	9.30	1.36	0.31	2.20
92.0	2.5	5	0.5	13.30	130/145/125	8.72	1.37	0.27	1.48
89.5	5	5	0.5	13.27	130/145/125	9.31	1.39	0.22	1.55
87.0	7.5	5	0.5	13.24	130/145/125	8.94	1.41	0.20	1.69
84.5	10	5	0.5	13.21	130/145/125	9.28	1.42	0.21	1.81
82.0	12.5	5	0.5	13.12	130/145/125	9.40	1.44	0.14	1.97
90	10	0	0	13.50	130/145/125	8.94	1.08	0.27	1.81
90	10	0	0	14.00	130/145/125	8.48	1.08	0.28	1.75
90	10	0	0	14.50	130/145/125	8.40	1.08	0.32	1.77
90	10	0	0	15.00	130/145/125	8.86	1.08	0.34	1.75
90	10	0	0	15.50	130/145/125	8.54	1.08	0.39	1.75
90	10	0	0	16.00	130/145/125	8.42	1.08	0.4	1.76
90	10	0	0	16.50	130/145/125	9.01	1.08	0.41	1.87
90	10	0	0	14.00	110/125/125	8.47	1.08	0.47	1.89
90	10	0	0	14.00	120/135/125	8.68	1.08	0.41	1.83
90	10	0	0	14.00	130/145/125	8.42	1.08	0.36	1.80
90	10	0	0	14.00	140/155/125	8.57	1.08	0.24	1.79
90	10	0	0	14.00	150/165/125	8.41	1.08	0.15	1.83
90	10	0	0	14.00	160/175/125	8.66	1.08	0.16	1.82

content in extrudates, observed by certain researchers. However, no clearly definable effect of the process parameters on the protein content changes in question was observed.

Increase in the content of pea hulls in the product resulted in increased protein content, crude fat content, crude fibre and ash content. There was also an increase in the content of all the fractions of detergent fibre (Fig. 8) and of total dietary fibre, including the soluble and insoluble fractions (Fig. 9).

Extrusion cooking had a significant effect on the content of dietary fibre in the processed raw material. Analysing changes in the content of crude fibre and detergent fibre fractions - NDF, ADF and HCEL – in the raw materials and in the extrudates produced from them we can note that extrusion leads to degradation and, at the same time, to a reduction of determinability of crude fibre (Fig. 7) as well as of detergent fibre fractions NDF and HCEL (Fig. 10). No significant changes were observed in the content of total dietary fibre (determined with the enzymatic method). However, there was a notable decrease in the content of the insoluble fraction and an increase in that of the soluble fraction of dietary fibre (Fig. 11). Similar trends were observed by Rzedzicki *et al.* (2004a) who extruded corn semolina with a 40% admixture of pea hulls. In that case, however, the authors observed a decrease in the content of total dietary fibre. Literature data concerning the effect of extrusion on the content of dietary fibre are divergent. Ralet *et al.* (1993), Camire (2000) report that as a result of the process there is a decrease in the content of insoluble fraction of dietary fibre, while the content of the soluble fraction increases.

Increase in the content of soluble fraction and decrease in that of insoluble fraction of dietary fibre were observed *eg* in extruded wheat products (Björck *et al.*, 1984), oat products (Camire, 2000), and in extruded pea hulls (Ralet *et al.*, 1993). Singh *et al.* (2007) suggested that changes in the content of dietary fibre fractions depend on the kind of material processed. According to those authors, in extruded wheat, barley (non-hulled) or oat materials, there was an increase in the content of soluble dietary fibre, while in extruded potato peels the content of the soluble fraction decreased. Fornal *et al.* (1993), extruding multicomponent cereal blends, recorded lower content of insoluble fibre fraction in the extruded products. According to those authors, the extent of the changes depended largely on the raw material composition of the extruded blends. For corn extrudates with 10 and 15% admixture of wheat bran, the reduction in insoluble fibre content was 50.11 and 61.71%, respectively, while for corn extrudates with 5% content of rye bran and 5% admixture of buckwheat meal the reduction in the content of that fibre fraction was only 29%. Similar trends were observed by Lukešova *et al.* (1996) who subjected a variety of cereal materials to the process of extrusion. In their case the differences in the content of insoluble fibre in the raw materials and in the extrudates

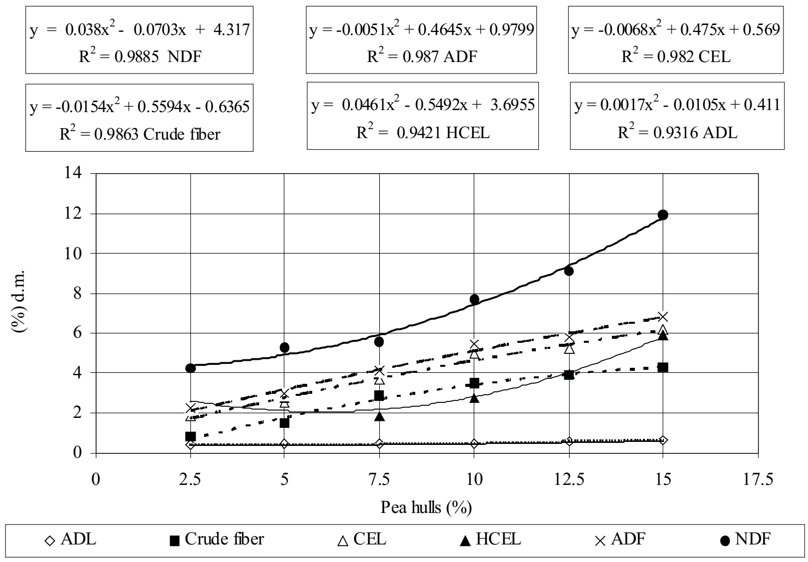

Fig. 8. Influence of pea hulls concentration on the content of the crude fibre and detergent fibre (oat bran – 3.5%, temperature – 145°C).

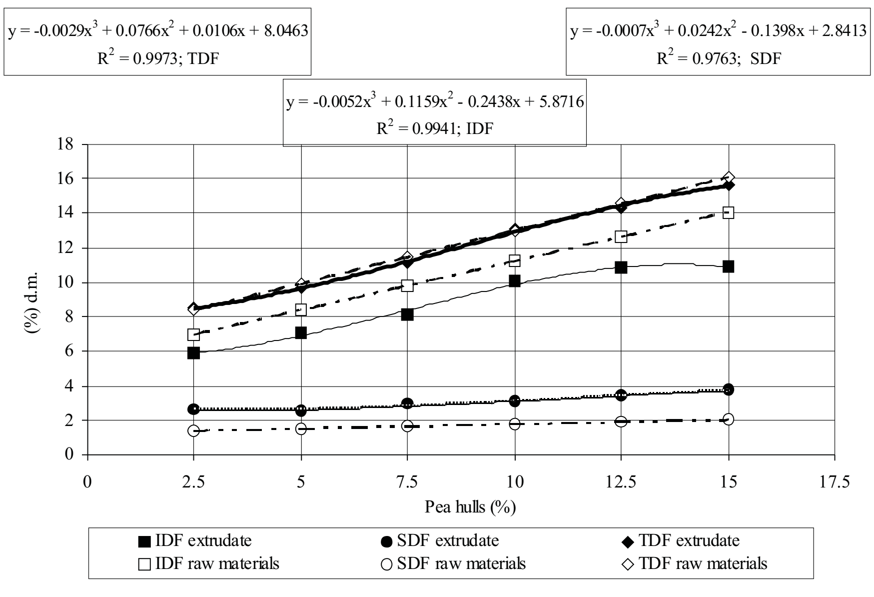

Fig. 9. Influence of pea hulls concentration on the content of the total dietary fibre (TDF) and its IDF and SDF fractions (oat bran – 3.5%, temperature – 145°C).

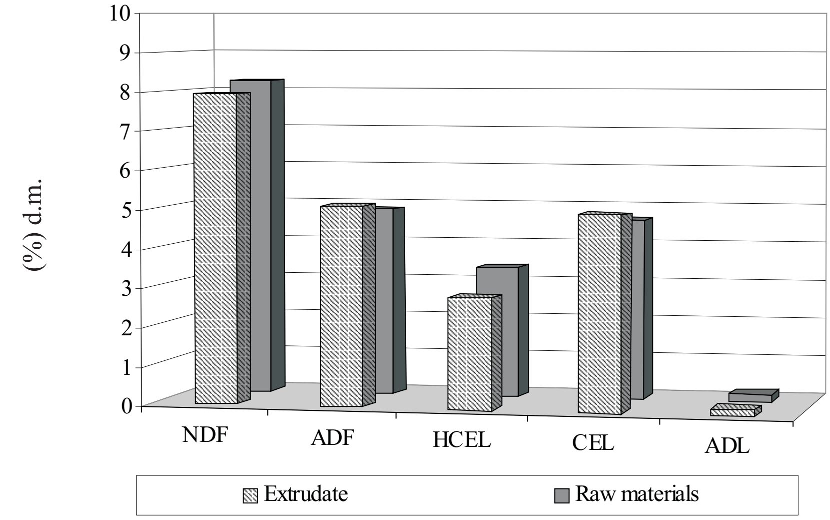

Fig. 10. Comparison of the detergent fibre composition of raw materials and extrudate (pea hulls – 10% and corn semolina – 90%, temperature – 145°C, moisture content – 13.5%).

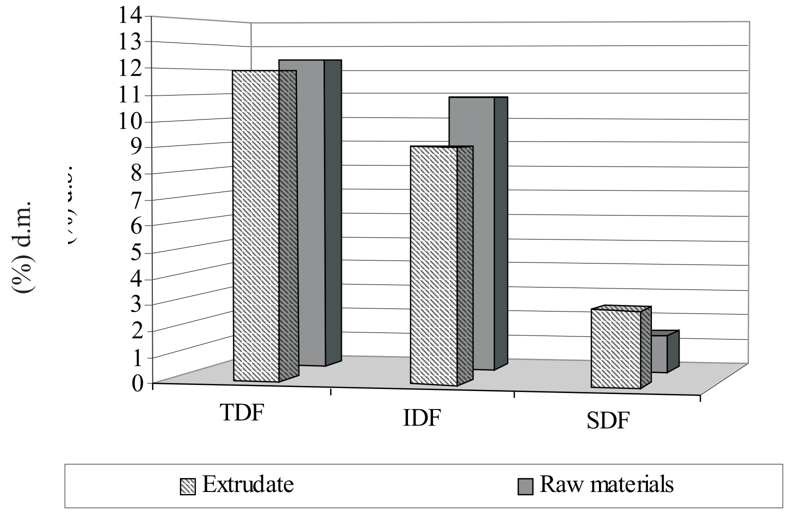

Fig. 11. Comparison the content of the total dietary fibre (TDF) and its IDF and SDF fractions of raw materials and extrudate (pea hulls – 10% and corn semolina – 90%, temperature – 145°C, moisture content – 13.5%).

produced were notably lower and fell within the range from 10 to 27%. Extrusion leads to a lowering of the content of total dietary fibre, including a reduction in the level of the insoluble fibre fraction and an increase in the content of the soluble fibre fraction (Ralet *et al.*, 1993; Singh *et al.*, 2007). Kahlon *et al.* (1998) did not observe any change in the content of dietary fibre in extruded oats, corn, wheat bran, and rice. Analysing changes in the content of dietary fibre and its particular fractions one should keep in mind that in the course of the process there may occur partial degradation of molecular mass of fibre components and lowering of their determinability on the one hand, while on the other hand extrusion may be conducive to the formation of new fibre components *eg* resistant starch or products of the Maillard reaction (Singh *et al.*, 2007). Therefore, the content of dietary fibre fractions determined in extrudates is a resultant of the above processes.

Analysing changes in the content of dietary fibre determined with the enzymatic method as a function of variable process parameters – moisture content of the processed raw material (Fig. 12) and of the variable process temperature (Fig. 13) – no significant changes were observed, either in the content of the total dietary fibre or of its particular fractions. It should be emphasized, however, that every time in the extrudates obtained at the various process parameters the content of insoluble dietary fibre fraction was lower

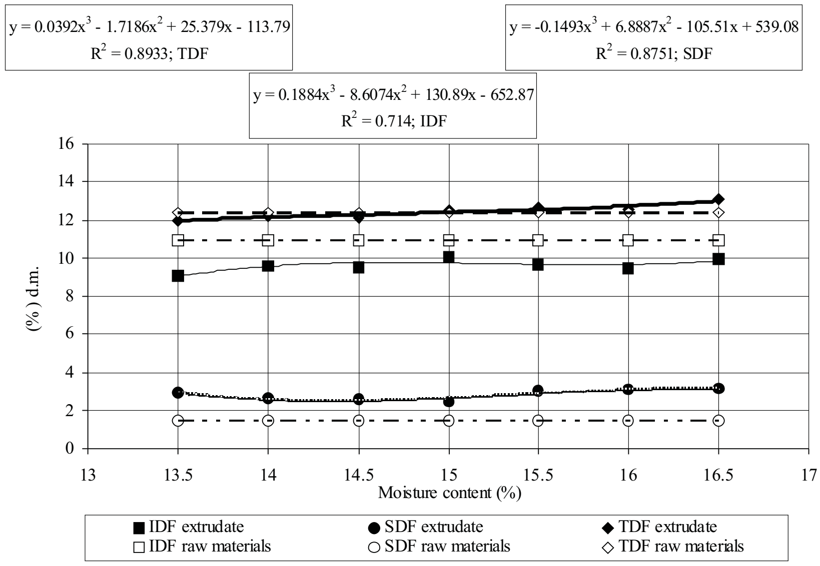

Fig. 12. Influence of moisture content of the raw material on the content of the total dietary fiber (TDF) and its IDF and SDF fractions (pea hulls – 10% and corn semolina – 90%, temperature – 145°C).

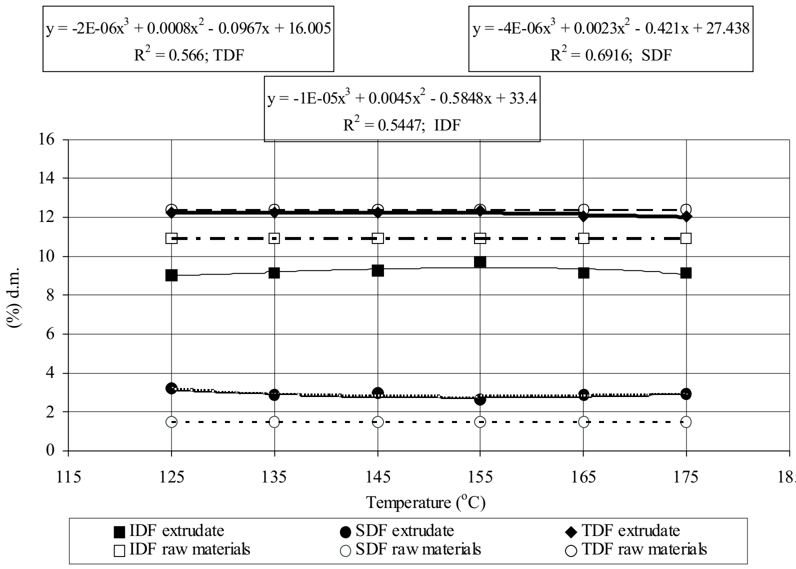

Fig. 13. Comparison the content of the total dietary fibre (TDF) and its IDF and SDF fractions of raw materials and extrudate (pea hulls – 10% and corn semolina – 90%, temperature – 145°C, moisture content – 13.5%).

compared to the raw materials. Opposite tendencies were observed in the case of the soluble fibre fraction. Changes in the content of dietary fibre and its individual fractions were also the subject of a study by Martin-Cabrejas *et al.* (1999). Those authors, extruding bean meal with variable moisture content of 25 and 30%, respectively, demonstrated that with increase in process temperature from 140 to 180ºC there was an increase in the content of soluble dietary fibre fraction with simultaneous decrease in the content of the insoluble fibre fraction. The observed changes were greater for the higher level of material moisture content (30%).

Analysis of the effect of extrusion parameters on changes taking place in the particular fractions of detergent fibre showed that increase in raw material moisture content within the range of 13.5-15.5% had no significant effect on the level of the NDF and ADF fibre fractions in the product (Fig. 14). The constant level of acid-detergent fibre, observable within the moisture range in question, is a result of slight decrease in cellulose content and simultaneous increase in lignin content. Further increase in raw material moisture, from 15.5 to 16.5%, causes a slight increase in the

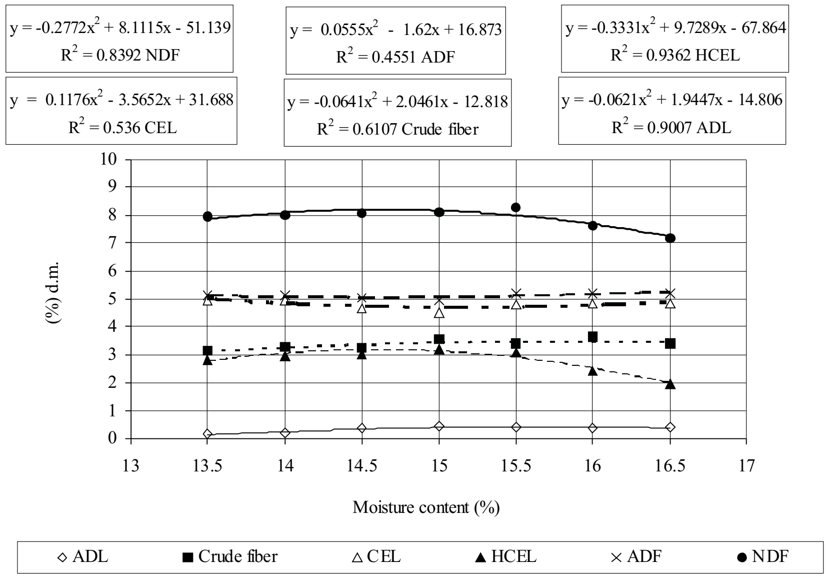

Fig. 14. Influence of moisture content of the raw materials on the content of the crude fibre and detergent fiber (pea hulls – 10% and corn semolina – 90%, temperature – 145°C).

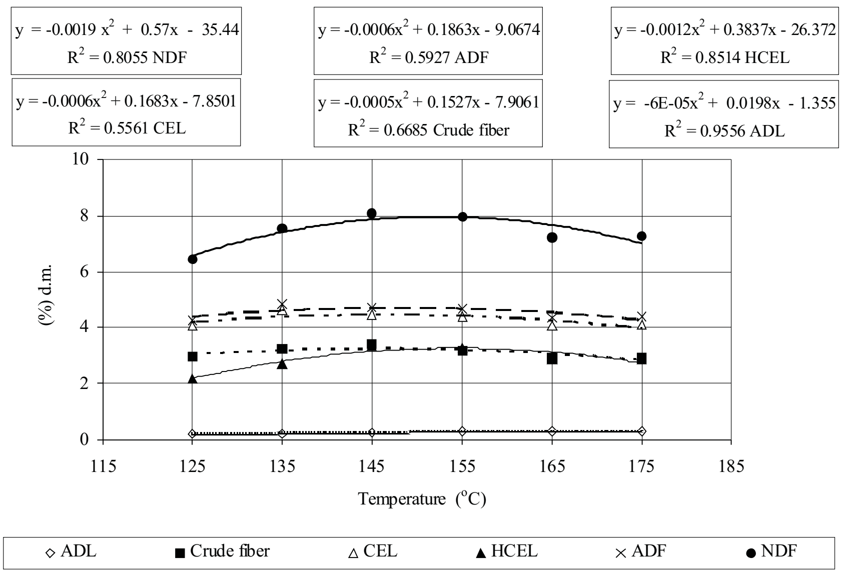

Fig. 15. Influence of barrel temperature on the content of the crude fibre and detergent fibre (pea hulls – 10% and corn semolina – 90%, moisture content – 14%).

content of ADF fraction. The observed changes are due to a significant increase in cellulose content within the moisture range under discussion.

Interesting trends were noted when analysing changes in the content of particular fibre fraction in the function of the process temperature (Fig. 15). With increase in extrusion temperature from 125 to 145°C, increase in the content of the NDF fraction is observed, from 6.43 to 8.09%. The fibre fraction that appears to be primarily responsible for increase in the content of NDF is the hemicellulose fraction, as the content of acid-detergent fibre (ADF) increased within that temperature range by only 10%. Theander and Westerlund (1984) suggested that increase in the level of dietary fibre in extrudates, resulting from increase in the process temperature, is related to increasing content of resistant starch. With further increase in the process temperature (155-175°C), a decrease was recorded in the content of the particular fibre fractions. One should assume then that intensification of the process parameters leads to increased degradation of the molecular mass of non-starch polysaccharides and causes an increase in their solubility in both neutral and acid detergent solutions. Consequently, the determined content of the particular fibre fraction is reduced.

CONCLUSIONS

1. Single-screw extrusion of corn semolina blends enriched with a 2.5-15% admixture of pea hulls proceeded correctly within a broad range of the process parameters.

2. Water solubility index of extrudates enriched with admixture of pea hulls was relatively very low and was in the range of 15-16% (process temperature 145°C, moisture content 13.5%).

3. Increase in the content of pea hulls in the product, from 2.5 to 15%, resulted 2-fold increase in total dietary fibre.

4. As a result of extrusion, reduced content of crude fibre and free fat was observed, and a slight reduction in the content of proteins.

5. The process of extrusion cooking led to a lowering in the content of detergent fibre fractions.

6. Extrusion caused a notable reduction in the content of insoluble dietary fibre fraction and an increase in that of the soluble fibre fraction. No significant changes were observed in the content of total dietary fibre.

7. The percentage content of pea hulls in the blends had no significant effect on the viscosity of extrudates.

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