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APPLICATION OF PEA HULLS FOR EXTRUDATE PRODUCTION

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A research was undertaken to determine the effect of the concentration of pea hulls (a by-product of the industrial dehulling of pea seeds) and parameters of extrusion-cooking process on the chemical composition of extrudates obtained with the use of a twin-screw extrusion-cooker (extruder). It was shown that the concentration of pea hulls in extrudates can reach up to 80%. The extrusion-cooking process resulted in a decrease in the contents of lipid, protein, dietary fibre (TDF) and its insoluble fraction (IDF) as well as caused an increase in the content of the soluble fraction of fiber (SDF). These changes depended on the composition of the mixture subjected to the extrusion-cooking process and on the following process parameters: temperature and moisture content of raw material.

INTRODUCTION

In the last century, humans have significantly changed their environmental conditions, lifestyle and dietary habits. These changes have resulted among others in an increasing percentage of people suffering from civilisation diseases, including diseases of the circulatory system, cancers, diabetes and obesity. Thus, searching for the possibility of returning to our prehistorical menu seems reasonable, and all the achievements of modern food technology should be oriented towards making it the most attractive.

The nutritional studies conducted for many years have proved that the dietary fibre is a substantial and indispensable component of food [Aldoori *et al.*, 1997; Rowland, 2001; Kritchevsky, 2001; Burkitt, 1995]. In spite of confirmed, beneficial influence of dietary fibre on humans, its consumption in many European countries is still lower than the recommended standards [Gibney, 2001]. Many technologies applied in cereal processing treat this food component as useless ballast, decreasing the functional and sensory quality of products. High quality flours and other cereal products are being efficiently cleaned from the hull – the main source of dietary fibre. The industrial dehulling of legume seeds, to be applied for food uses, is another example of decreasing dietary fibre concentration in a diet.

Recently studies have been carried out on the possibility of applying pea seed hull, being a by-product of industrial dehulling of pea seed, in food products [Troszyńska *et al.*, 2000]. This product, in industry referred to as "pea meal", was demonstrated to be a valuable source of not only dietary fibre but also of biologically-active compounds, including phenolic ones favourably affecting human health [Troszyńska *et al.*, 1997, 2002; Troszyńska & Bałasińska, 2002]. The earlier studies proved that the extrusion technology having many advantages (eliminates legume flavour, guarantees microbiological purity, makes products attractive by forming their proper shape and improving their structure), can be applied in pea hulls processing in order to obtain high-dietary fibre extrudates [Rzedzicki *et al.*, 2004].

The aim of this study was to determine the effect of pea hulls concentration and parameters of the extrusion cooking process: temperature, moisture content of raw material as well as die diameter on the chemical composition of extrudates obtained with the use of a counterrotating twin--screw extrusion-cooker (extruder).

MATERIALS AND METODS

Pea hulls obtained during industrial dehulling of pea (*Pisum sativum* L.), variety Opal, were used as the experimental material. Commercial corn semolina, obtained from PZZ Włocławek, was also used in the study as the main cereal material.

Extrusion-cooking of the pea hulls. The pea hulls were used for extrusion cooking with a cereal component (corn semolina) in various rations as given in Table 2. For the extrusion, the material was ground in a universal hammer mill (H 111/3, Poland) using sieves of 3-mm diameters. The mixtures were moistened to a recommended moisture content and conditioned for 12 h in order to provide uniform water diffusion in the whole mass. The mixtures prepared in such a way were subjected to extrusion using a twin-screw extrusion-cooker (type 2S 9–5, Metalchem, Gliwice, Poland). The parameters of the extrusion-cooking process (*i.e.* moisture content of the raw material, extrusion temperature, die diameter) and the concentration of pea hulls in a mixture subjected to the extrusion (Table 2)

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were determined on the basis of the previous studies. Only parameters that guaranteed a stable course of the extrusion process and simultaneously enabled obtaining high quality products were selected [Rzedzicki *et al.*, 2004].

Chemical analysis. The raw materials and extrudates obtained were determined for the contents of crude protein [AACC, Method 46-08, N × 6.25), crude fat [AACC, Method 30–10], ash [AACC, Method 08–01], dietary fibre (TDF) – its soluble (SDF) and insoluble (IDF) fractions (using procedures and enzymes of Megazyme Corporation [AOAC Method 991.43; AOAC Method 985.29; AACC Method 32–07; AACC Method 3221; AACC Method 32–05]).

Statistical analysis. Statistical analysis and regression analysis were performed using Microsoft Excel procedures (Microsoft Office XP software).

RESULTS AND DISCUSSION

The contents of basic chemical components and dietary fibre of the raw materials are presented in Table 1. The obtained results demonstrated that the by-product obtained during industrial dehulling is characterised by a higher concentration of nutrients than corn semolina widely applied in the production of food extrudates. The content of protein, fat, ash and dietary fibre (TDF) in pea hulls was higher by *ca.* 4.5, 0.8, 3.5 and 56.6%, respectively, compared to corn semolina. Attention should be paid to a high protein content of pea hulls, the source of which are the cotyledon fragments passing into the by-products during the process of seed dehulling. However, the main component of pea hulls is the dietary fibre. It consists of fractions that can be divided (from the analytical point of view) into soluble – SDF (pectic substances, most of hemicelluloses and some of polysaccharides) and insoluble – IDF (cellulose, lignin, and some

TABLE 1. Chemical composition of the raw materials (% d.b.).

Material	Protein N × 6.25	Fat	Ash	TDF	IDF	SDF
Maize	11.1	1.0	1.3	6.25	5.26	0.99
Pea hulls	15.6	1.8	4.8	67.65	61.84	5.81

The results were calculated as mean values of three replications.

TABLE 2. Model of experiments and chemical composition of the extrudates (% d.b.).

Extrudate No.	Share rate (%)		Moisture (%)	Temp. (°C)	Die diam. (mm)	Protein	Fat	Ash
	Maize	Pea hulls						
1	80	20	14	130/160/200/180/130	6	10.1	0.5	2.3
2	70	30	14	130/160/200/180/130	6	10.1	0.5	2.4
3	60	40	14	130/160/200/180/130	6	12.2	0.5	2.8
4	50	50	14	130/160/200/180/130	6	12.6	0.8	3.1
5	40	60	14	130/160/200/180/130	6	11.6	0.9	3.3
6	30	70	14	130/160/200/180/130	6	12.3	1.0	3.6
7	20	80	14	130/160/200/180/130	6	12.55	1.16	4.0
8	80	20	17	130/160/200/180/130	3.2	9.4	0.3	2.1
9	70	30	17	130/160/200/180/130	3.2	11.0	0.3	2.5
10	60	40	17	130/160/200/180/130	3.2	11.9	0.5	2.7
11	50	50	17	130/160/200/180/130	3.2	11.8	0.7	3.0
12	40	60	17	130/160/200/180/130	3.2	13.4	0.9	3.4
13	30	70	17	130/160/200/180/130	3.2	13.7	1.0	3.6
14	20	80	17	130/160/200/180/130	3.2	13.9	1.2	3.9
15	60	40	14	130/160/200/180/130	3.2	10.9	0.6	2.7
16	60	40	17	130/160/200/180/130	3.2	10.9	0.5	2.7
17	60	40	20	130/160/200/180/130	3.2	11.3	0.6	2.8
18	60	40	23	130/160/200/180/130	3.2	11.2	0.4	2.8
19	60	40	26	130/160/200/180/130	3.2	11.2	0.5	2.8
20	60	40	14	80/100/120/100/130	3.2	11.6	0.7	2.8
21	60	40	14	100/120/145/125/130	3.2	11.2	0.6	2.8
22	60	40	14	120/140/170/150/130	3.2	12.1	0.8	2.8
23	60	40	14	140/160/195/175/130	3.2	11.8	0.8	2.9
24	60	40	14	160/180/220/200/130	3.2	11.5	0.7	2.8

The results were calculated as mean values of three replications.

of hemicelluloses) [Prosky, 1986]. The analysis conducted showed that the main fraction of pea hulls was the insoluble (IDF) one reaching up to 91.3% of total dietary fibre. The data presented in Table 1 demonstrate a high dietetic value of pea hulls and suggest the necessity of their application for food uses. As raw material, the pea hulls can be used for the enrichment of the cereal-based extrudates in such components as proteins, mineral compounds and dietary fibre.

The basic chemical composition of the extrudates, based on pea hulls and corn semolina, at different parameters of the extrusion process was presented in Table 2. It was shown that the broad range of the pea hulls concentration (from 20% to 80%) in a mixture with corn semolina resulted in modification of the chemical composition of the extrudates. Comparing the chemical composition of raw material with the extrudates obtained, it can be concluded that, under experimental conditions, the extrusion process caused a decrease in lipid and also a slight decrease in protein content. Whereas the content of ash remained at a similar level. These changes presented in Figure 1, were exemplified by a sample processed under the following conditions: concentration of pea hulls – 40%, concentration of corn semolina – 60%, temperature – 200°C, moisture content of raw material – 14%, and the die diameter – 6 mm. The decrease in fat content during the extrusion-cooking process was confirmed by the studies of many authors [Guzman *et al.*, 1992]. It is connected with the formation of fat complexes with other compounds, mainly with starch and protein, which results in the reduction of its extractability with non-polar solvents. According to Guzman *et al.* [1992], the differences between lipid extracted from raw material and lipid extracted from the extrudates were a specific measure of fat complexing during the process. The results obtained demonstrated that complexing of fat was highly dependent on pea hull concentration in the mixture. In the samples with a 20% addition of the pea seed coat, the degree of fat complexing equalled to 61.2%. Whereas, an increase in the concentration of this high dietary fibre component up to 80% resulted in a decrease in the index value to 27.5%. Wang *et al.* [1993] suggested that the degree of fat complexing during extrusion depends on starch content in processed material which facilitates the formation of starch-lipid complexes. The results obtained seem to incline similar suggestions, since, along with an increase in the concentration of the high dietary fibre component, the starch content and the degree of lipid

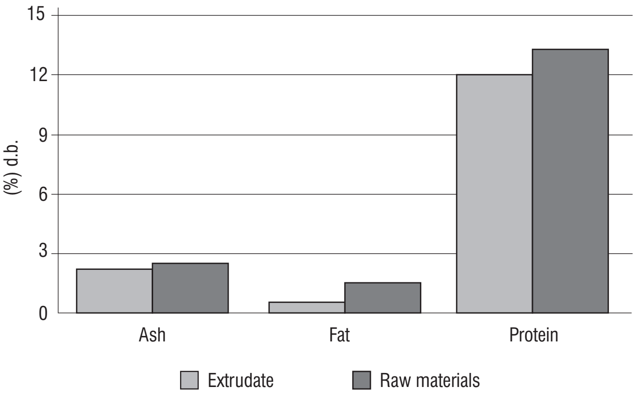

FIGURE 1. Comparison of the chemical composition of raw material and extrudate (40% of pea hulls and 60% of corn semolina; temp. – 200°C; moisture content – 14%; die diameter – 6 mm).

complexing decreased. The extrusion process results also in the reduction of protein content in processed raw material (Figure 1). The noted changes are not significant, however they refer to all the analysed samples. Similar observations were made by Zieliński *et al.* [2001], Makarski *et al.* [2002]. Stanley [1989] claimed that the isopeptide bonds between ε-amine group of lysine and amide group of asparagines or glutamine can be formed during the extrusion-cooking process. The reaction of the amino acids condensation results in the release of ammonia. This way the author explains a slightly lower protein content of extrudates reported by some researchers.

Figure 2 presents the influence of pea hulls concentration on the content of total dietary fibre (TDF), its insoluble (IDF) and soluble (SDF) fractions in raw material as well as in extrudates. It was shown that increasing the concentration of pea hulls from 20% to 80% in raw mixture resulted in highly differentiated content of TDF, IDF and SDF in the extrudates obtained, *i.e.* from 15.66% to 54.19%, from 12.66% to 48.27%, and from 3.02% to 5.92%, respectively. Comparing the contents of dietary fibre and its fractions in raw material with these in the obtained extrudates, it should be stated that the extrusion process caused an increase in SDF and simultaneously a decrease in TDF as well as in SDF contents. That tendency was constant in the whole experiment model (Figures 2, 3, 4). Since different authors apply different analytical methods for dietary fibre determination, it was difficult to compare the results obtained with the literature data [Fornal *et al.*, 1993].

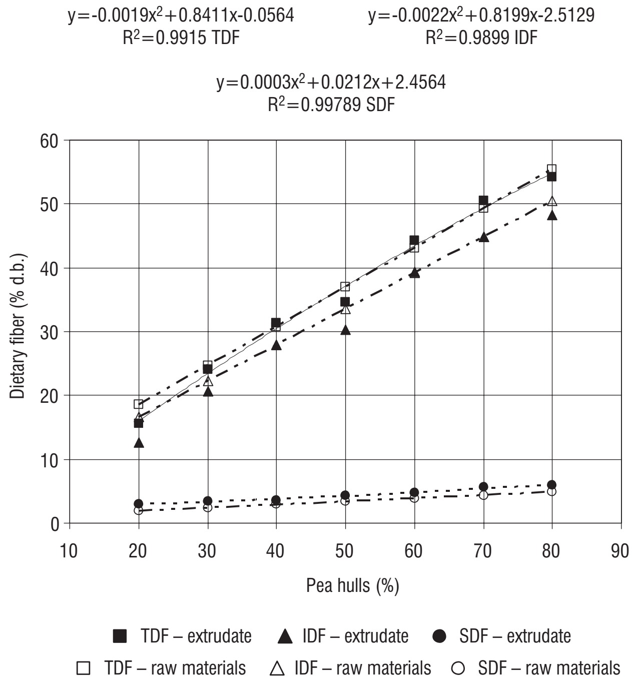

FIGURE 2. Influence of pea hulls concentration on the content of the total dietary fibre (TDF) and its IDF and SDF fractions (die diameter – 6 mm; temp. – 200°C; moisture content – 14%).

An analysis of the effect of raw material moisture content on dietary fibre content indicated that along with moisture increasing, a constant increase in SDF was observed. While, TDF and IDF reached their extrema at the moisture content equal to 23%, showing a typical inflexion point of the curve (Figure 3). The results presented in Figure 3

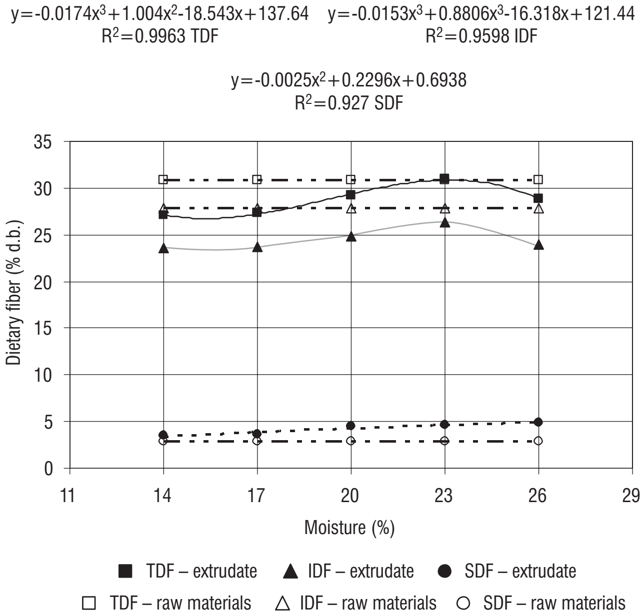

FIGURE 3. Influence of moisture content of the raw material on the content of the total dietary fiber (TDF) and its IDF and SDF fractions (pea hulls – 40%; temp. – 200°C; die diameter – 3.2 mm).

should be carefully interpreted. Without making allowances for the curves of the expected values (resulting from the raw material composition), it may be concluded that with moisture content increasing from 14% to 23%, changes in the processed material appear to be the most intensive, leading to an increase in TDF and IDF values. However, when we compare these results with the curves of the expected values, the most intensive changes are likely to proceed at a moisture content of 14% (at which the lowest TDF and IDF values were reported).

While analysing the influence of temperature on dietary fibre content, the typical inflexion point of the curve was observed at a temperature of 195°C (Figure 4). Along with

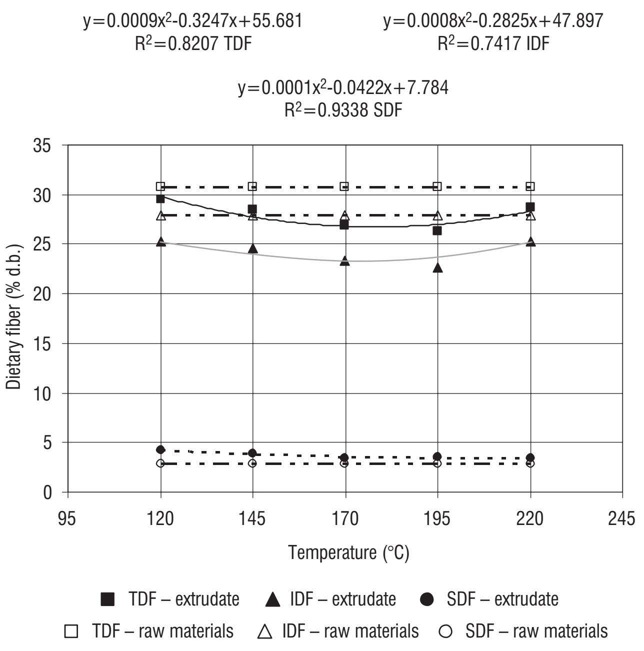

FIGURE 4. Influence of barrel temperature on the content of the total dietary fiber (TDF) and its IDF and SDF fractions (pea hull – 40%; die diameter – 3.2 mm; moisture content – 14%).

temperature increasing, a decrease in the values of TDF and IDF was observed. The lowest values were noted at a temperature of 195°C. At a temperature of 220°C, again a rapid increase in the values of these components was observed. If these results are considered in respect of the expected values curves, significant changes of dietary fibre along with temperature increase can be observed. At temperatures above 195°C, the process of resistant structures formations (most probably of resistant starch) appears to predominate as well as contents of IDF and TDF fractions are observed to increase.

In spite of a broad range of moisture content and temperature of a barrel, the observed changes in the contents of dietary fibre fractions were not radical, which undoubtedly resulted from the type of the extrusion-cooker used. The 2S-9/5 extrusion-cooker is a counterrotating extruder with constant configuration of the screws and rigid characteristic of residence time distribution of raw material inside the barrel. Therefore the degradation processes are reduced therein. The studies indicated the possibility of modifying dietary fibre content in extrudates through changing the ratio of high fibre component in the mixtures subjected to the extrusion process.

The 2S 9–5 twin-screw extrusion-cooker applied in the studies enables processing the mixtures with pea hulls concentration from 20% to 80%. The tests of introducing higher concentrations of the pea hulls were proved unsuccessful. A low bulk density, characterising the raw material, affects a low packing degree of the working space inside the barrel of the extrusion-cooker. Consequently, the processed material is burned and the destabilization of the extrusion process is also observed [Rzedzicki *et al.*, 2004].

CONCLUSIONS

It was found that the pea hulls being the by-product of the industrial dehulling can be applied for the enrichment of cereal-based extrudates in nutrients and dietary fibre. The concentration of the pea hulls in extrudates obtained with the use of the twin-screw extrusion-cooker can reach up to 80%. The concentration of nutrients and dietary fibre in the extrudates can be modified to a high extent applying different concentrations of the pea hulls in the raw mixture (from 20% to 80%). The analysed parameters of the extrusion process, such as: temperature and moisture content of raw material, resulted in a decrease in the content of dietary fibre and its insoluble fraction as well as an increase in the content of its soluble fraction.

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WYKORZYSTANIE ŁUSKI GROCHOWEJ W PRODUKCJI EKSTRUDATÓW

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Badano wpływ udziału łuski grochowej (produkt uboczny przemysłowego odłuszczania nasion grochu) i parametrów procesu ekstruzji na skład chemiczny ekstrudatów uzyskanych przy zastosowaniu ekstrudera dwuślimakowego przeciwbieżnego. Wykazano, że udział łuski grochowej w ekstrudatach może wynosić do 80%. Proces ekstruzji wpływał na obniżenie zawartości tłuszczu, białka, błonnika pokarmowego (TDF) i jego frakcji nierozpuszczalnej (IDF) w produktach oraz powodował wzrost zawartości frakcji rozpuszczalnej (SDF). Wielkość tych zmian zależała od składu ekstrudowanej mieszanki i od parametrów procesu takich jak temperatura i wilgotność surowca.