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Effect of pea seed coat admixture on physical properties and chemical composition of bread

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A b s t r a c t. A study was made on the effect of an admixture of pea hulls (*Pisum sativum* L.) and of the degree of their fragmentation on the results of test laboratory baking (dough yield, bread yield, oven loss, total baking loss), on the physical properties of the bread (volume of 100 g of bread, crumb porosity, water absorption index value, water solubility index value, and on the chemical composition of the bread, including moisture content, protein, crude fibre, particular fractions of detergent fibre, dietary fibre as well as on the results of sensory assessment. The study showed that pea hulls, applied at levels of up to 10%, may be a good source of dietary fibre in bread, while retaining its white colouring, similarity to traditional wheat bread, and acceptable physical properties and sensory values.

K e y w o r d s: white bread, dietary fibre, pea hulls, physical properties

INTRODUCTION

In view of the pandemia of civilization diseases, cereal products, and especially bread, play a highly important role in human nutrition. In Poland the consumption of bread per person in 2004 was *ca*. 67 kg (Statistical Yearbook, 2006). Due to its level of consumption, bread is an important source of many nutrients, including proteins, dietary fibre, group B vitamins, and minerals (Borawska *et al*.,1999; Malinowska and Szefer, 2005). According to numerous authors (Paczkowska and Kunachowicz, 2003; Skibniewska *et al*., 2006), bread provides even up to 40% of dietary fibre consumed. The nutritious value of bread depends on its chemical composition, determined by the quality of the raw materials (flour, water) and additives applied (Giami *et al*., 2003; Lebiedzińska *et al*., 2006; Zdrojewska and Szefer, 2003).

White bread is consumed in the largest quantities, unfortunately it is characterized by low content of dietary fibre (Kasprzak and Rzedzicki, 2009). It is made of flours that do not contain the peripheral parts of the kernel and germ. The consumption of low-fibre white bread is considered by many researchers to be a major factor increasing the risk of civilization diseases (Gómez *et al*., 2003; Paczkowska and Kunachowicz, 2003; Rzedzicki *et al*., 2008).

Seeds of pulse plants, *eg* pea (*Pisum sativum* L.), are especially interesting sources of dietary fibre. Pea seeds are characterized by high protein content (19-29%), high content of lysine, high content of dietary fibre, and low content of fat. They also contain numerous biologically active compounds: inhibitors of trypsin, tannins, phytinians, lectines and oligosaccharides (Alonso *et al*., 2001; Honke *et al*., 1999; Pysz *et al*., 2001; Thanos, 1998). Numerous studies indicate that the above mentioned biologically active compounds are an important element of prophylaxis and control of civilization diseases (Troszyńska and Bałasińska, 2002; Wang *et al*., 1998).

Pea hulls, containing up to 65% of total dietary fibre, is a high valuable light-coloured by-product of the process of pea seeds dehulling. Studies conducted so far have demonstrated the usefulness of that material in the production of various extruded foods and breakfast cereals (Kasprzak and Rzedzicki, 2007, 2008; Rzedzicki *et al*., 2004a).

In view of the above, the authors undertook a study on the possibility of applying that valuable material in the production of bread with increased content of high-fibre components while ensuring similarity of the product (external appearance, volume of 100 g of bread, crumb porosity, taste and flavour) to the traditional white wheat bread.

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MATERIAL AND METHODS

The material used in the study was wheat flour (WF) type 550 and pea hulls cv. Opal. The pea hulls was grinded using a universal impact grinder type H-111/3 until obtaining the required level of mean diameter and share rate of required fractions. Following repeated fragmentation, the pea hulls were separated into fractions with outer diameters of φ_z = 0.28 mm (PHS) and φ_z = 0.86 mm (PHC) (Table 1). The dough was prepared according to the direct method (Institute of Baking, Berlin), in compliance with the adopted model of the experiment (Table 2). The following components were added: water – 450 ml, NaCl – 1.5%, and yeast – 3%. The pulse component was applied at varied rates, from 2.5 to 10% for each of the pea hulls fractions. The dough kneading time applied in the study was constant at 10 min. Proofing of the dough was conducted so that the dough yield was 155% for all kinds of bread. Dough portions of 250 g were baked at temperature of 230ºC for 30 min.

Estimation of the quality of control (wheat) and wheat-pulse breads was made after 24 h from baking. The estimation of the test laboratory breads included determination of dough yield, bread yield, oven loss and total baking loss. Estimation of the physicochemical properties of the breads included determination of the volume of 100 g of bread, crumb porosity, water solubility index (WSI) (AACC, 88-04, as modified by Rzedzicki *et al*., 2004b), and water absorption index (WAI) (AACC, 88-04, as modified by Rzedzicki *et al*., 2004b). Measurements of water absorption (WAI) and water solubility index (WSI) were made using centrifuge loads of 2 200 g and constant time of centrifuging of 15 min. All measurements of physical properties were made in 4 replications.

Samples of the raw materials and of the breads were used for the determination of moisture content, ash content (AACC, Method 56-20), protein (AOAC, Method, 981,10), crude fibre (AACC, Method 32-10), fractions of detergent fibre: neutral-detergent fibre (NDF), acid-detergent fibre (ADF), hemicellulose (HCEL), celullose (CEL), acid-detergent lignin (ADL) with the method of Van Soest (1963a, b), and dietary fibre with the enzymatic method: soluble dietary fibre (SDF), insoluble dietary fibre (IDF), total dietary fibre (TDF) (AOAC, Method 991.43; AACC, Method 32-07; AACC, Method 32-21; AOAC, Method 985.29; AACC, Method 32-05). In the case of the enzymatic method, enzymes and procedures were used as recommended by Megazyme. Enzymatic activity was monitored with the use of the Megazyme control test. Every series of determinations included also control samples of starch and casein mixture.

The breads produced were also subjected to sensory evaluation covering the external appearance, crumb, crust, taste and flavour of the breads, using a 9-point scale. Control bread was used as the point of reference, and it was evaluated the maximum number of points. The evaluation was made by a team of 10 jurors with proven sensitivity to the sensory features under estimation.

T a b l e 1. Sieve analysis of the raw materials

Fraction (mm)	Quantity (%)
Wheat flour	
> 0.250	1.64
0.25-0.200	2.94
0.2-0.125	24.36
0.125-0.100	32.09
0.1-0.063	33.68
0.063-0.045	5.29
< 0.045	0.00
Mean diameter	0.12
Pea hulls small-grained	
> 0.500	4.41
0.5-0.400	17.50
0.4-0.315	30.20
0.315-0.200	24.80
0.2-0.100	17.98
0.1-0.063	5.11
< 0.063	0.00
Mean diameter	0.28
Pea hulls coarse-grained	
> 1.250	8.84
1.25-1.000	22.19
1.0-0.800	25.51
0.8-0.630	21.62
0.63-0.500	17.82
0.5-0.315	2.86
< 0.315	1.16
Mean diameter	0.86

Statistical analysis of the results was performed with the help of the SAS ver. 9.1 software package. In cases when the values of coefficient of variability exceeded the error limits for a given method, such results were rejected and the analyses were repeated.

RESULTS AND DISCUSSION

The produced control bread and wheat-pea bread (experimental) were characterized by good taste, flavour, and an interesting light colouring of crumb and crust. No cases of

T a b l e 2. Model of the experiment

Sample No.	Raw material	Share rate of component (%)		
		WF	PHS	PHC
1	WF	100	0	0
2	WF+PHS	97.5	2.5	0
3		95.0	5.0	0
4		92.5	7.5	0
5		90.0	10.0	0
6	WF+PHC	97.5	0	2.5
7		95.0	0	5.0
8		92.5	0	7.5
9		90.0	0	10.0

burning, intrusions or discolouring were observed. Crust thickness varied within the range from 2 to 3 mm. Crust to crumb adhesion was correct, with no gaps detected. Both the wheat-pea breads and the control bread were characterized by uniform crumb structure. The pores were thin-walled, with uniform sizes, which indicates correct fermentation of the dough.

The taste and flavour of the breads was specific, aromatic, with no foreign traces. With pea hulls levels up to 10% the jurors did not detect any pea flavour.

With increase in the level of pea hulls addition a decrease was observed in the number of points awarded to the breads (Table 3). However, this does not mean that any of the breads were disqualified. They were somewhat different than the wheat breads to which the jurors are traditionally accustomed. Breads containing 2.5% admixture of both the small-grained (PHS) and coarse-grained (PHC) pulse material were awarded 8.73 and 8.65 pts., respectively, which indicates very good quality and full acceptability of the breads to the jurors. It should be emphasized that for all the bread kinds under estimation slightly higher marks were awarded to breads with addition of small- grained pea hulls (PHS) compared to breads containing coarse-grained hulls (PHC) (Table 3). A lowering of sensory evaluation of breads with increase in the level of addition of various high-fibre components was also noted by El-Adawy (1997) and Gómez *et al*. (2003).

The addition of pea hulls had only a slight effect on increase in bread yield compared to the control. For the control bread the yield was 131%, while in the case of breads with the highest (10%) level of small-grained – PHS, and coarse-grained – PHC pea hulls the bread yield values were slightly higher at about 133% (Table 3). Similar results were obtained also by other authors (Gambuś *et al*., 1999, 2002; Korus and Achremowicz, 2004). Gambuś *et al*. (1999), introducing a 10% admixture of extruded triticale bran, observed an increase in bread yield value by about 4% with relation to the control.

The application of pea hulls had a slight decreasing effect on the values of oven loss and total baking loss (Table 3). At 2.5% level of the small-grained (PHS) and coarse-grained (PHC) pulse component the oven loss was 13.05 and 13.12%, respectively. The values of the total baking loss for the wheat-pea breads varied within the range from 13.73 to 15.32%, while for control bread the recorded value was 15.47%. It should be noted that slightly higher values of total oven loss were obtained in the case of breads with an admixture of PHC (Table 3). Gambuś *et al*. (1999) also recorded a decrease in oven loss and total baking loss following the application of a high-fibre component in the recipe; applying a 10% admixture of grasspea seeds they obtained an oven loss reduction of 0.8% and total baking loss reduction of 0.4% in relation to the control bread.

T a b l e 3. Results of physical properties and sensory evaluation

Sample No.	Yield of bread	Oven loss	Total baking loss	Sensory evaluation	Bread volume	Crumb porosity
	(%)			(pts)	(cm^3 100 g^{-1})	(%)
1	131.00±0.66	13.62±0.30	15.47±0.43	9.00	385±10.56	71.37±9.06
2	131.49±1.01	13.05±1.14	15.32±0.65	8.73	375±14.16	66.67±0.00
3	132.24±0.66	13.12±0.62	14.64±0.64	8.28	321±13.00	55.60±5.17
4	133.00±0.66	12.90±0.83	13.83±0.43	8.09	279±7.51	51.85±5.24
5	133.28±1.17	12.49±0.95	13.73±0.75	7.84	257±9.93	49.98±2.65
6	131.50±0.66	13.12±0.94	15.14±0.71	8.65	301±6.02	53.70±2.62
7	132.06±0.26	13.03±1.68	15.05±0.17	8.24	287±12.85	55.56±5.24
8	132.82±2.20	12.89±0.45	14.77±1.41	7.74	274±4.99	59.26±5.24
9	133.29±0.91	12.75±1.32	13.77±0.59	7.43	247±1.91	51.85±5.24

Explanatory notes: ± – standard deviation.

Bread volume and porosity are the first features that are evaluated by the consumer at the moment of purchase. With increase in the level of pea hulls a decrease was observed in the volume of 100 g of bread, both for the small-grained hulls - PHS (257-375 cm^3), and for the coarse-grained - PHC (247-301 cm^3) (Table 3). It needs to be emphasized that bread containing 2.5% admixture of small-grained pea hulls (PHS) was characterized by very good volume of 100 g, similar to that of the control bread. For the control bread that value was at the highest level of 385 cm^3. The relationships observed in this study are in agreement with results obtained by other researchers (Denli and Ercan, 2001; El-Adawy, 1997; Gómez *et al*., 2003; Kadan *et al*., 2001). Kawka (2005), applying an addition of high-fibre barley component, recorded a decrease in bread volume from 495 (for the control) to 451 cm^3. Conforti and Davis (2006), applying in wheat bread an admixture of 5% of soybean and 5% of flax, observed a decrease in bread volume by 87 cm^3 compared to the control bread.

The admixture of pea hulls, both small-grained and coarse, had an effect on bread crumb porosity. Among the bread types under examination, the highest crumb porosity was characteristics of the control bread for which the value of porosity was 71%. The smallest decrease in crumb porosity compared to the control bread was recorded for the 2.5% admixture of small-grained pea hulls (PHS) (Table 3). Breads with the highest – 10% – admixture of both small-grained and coarse-grained pulse component were characterized by the lowest crumb porosity of 49.98 and 51.85%, respectively (Table 3). Determinations of crumb porosity performed for control breads available on the Lublin market gave values within the range from 63 to 78% (Kasprzak and Rzedzicki, 2009). Karolini-Skaradzińska *et al*., (2006), applying an admixture of barley flour, and Kawka (2005), introducing a high-fibre barley component, also obtained a decrease in the values of the trait in question with increase in the level of the respective high-fibre components.

The raw materials applied in this study were characterized by varied values of the water absorption index WAI. The value obtained for the coarse pea hulls (PHC) was 487.70% d.m., for the small-grained pea hulls (PHS) 336.38%, and for the wheat flour (WF) 75.59% d.m. Low values were also obtained for the water solubility index WSI: WF – 4.72% d.m., PHS – 4.19% d.m., PHC – 11.29% d.m. (Table 4).

Determinations of water absorption and of the water solubility index were made for both the crust and the crumb of the breads. The application of the pulse component in amounts of 2.5-10% in the mixtures with wheat flour had a varied effect on the WAI values of the breads, depending on the kind of pea hulls applied (Table 5). If the coarse-grained pea hulls were used in amounts of 5 to 10%, a reduction in the crumb WAI value was observed, from 430.78 to 367.18% d.m. Whereas, the application of 2.5 to 7.5% of small-grained pea hulls caused opposite trends in the crust WAI values of the breads. In the case of using the coarse pea hulls in the experiments, higher values of WAI were recorded both for the crust and for the crumb. Among the breads tested, the highest water absorption of crust and crumb was characteristic of bread containing 5% admixture of coarse pea hulls (Table 5).

Table 4. Water absorption index (WAI) and water solubility index (WSI) of the raw materials

Raw material	WAI	WSI
	(% d.m.)	
WF	75.59±1.33	4.72±0.24
PHS	336.38±22.09	4.19±0.16
PHC	487.70±13.49	11.29±0.17

Changes in water absorption (WAI) were accompanied by changes in the values of the water solubility index (WSI). The WSI values of the control bread and the wheat-pea breads oscillated at fairly low levels, up to 12% d.m. (Table 5). This indicates low intensity of the process and negligible degradation of biopolymers. The obtained values of WSI are in strong contrast to those of 'crunchy breads' produced with the method of extrusion, for which the WSI values were even above 50% d.m. (Rzedzicki *et al*., 2008). Such great differences in WSI values prove the unquestionable superiority of traditional fermented bread compared to extruded 'crunchy bread'.

Samples of the breads produced were also used for chemical composition determinations. In all studied breads a lower moisture content was determined for the crust (19.08-22.39%) compared to the crumb (35.57-41.57%) (Table 5). Similar values of moisture were also obtained in examinations of breads available on the Lublin market (Kasprzak and Rzedzicki, 2009).

A slightly higher ash content, resulting from the chemical composition of the raw materials, was noted for the breads with admixture of small-grained pea hulls (Table 6). Ash content of the tested breads fell within a rather narrow range, from 1.61 to 2.17% d.m. (Table 7). The application of pea hulls addition to wheat control caused an increase in ash content.

Among the breads tested the lowest protein content - 10.82% d.m. (Table 7) – was characteristic of the bread with 10% content of coarse pea hulls, as the coarse-fragmented pea hulls contained only 8.05% d.m. of protein, whereas the small-grained pea hulls had nearly twice as high protein content (Table 6). The control bread had a protein content of

T a b l e 5. Water absorption index (WAI), water solubility index (WSI) and moisture content of crust and crumb

Sample No.	WAI		WSI		Moisture content	
	crust	crumb	crust	crumb	crust	crumb
1	394.30±12.80	306.82±12.33	8.57±0.18	9.31±0.4	19.08±0.95	41.51±1.91
2	366.00±21.48	291.60±8.24	9.43±0.55	9.66±0.35	19.52±1.12	41.39±0.59
3	374.37±6.74	346.46±8.92	8.22±0.91	9.13±0.23	19.79±0.38	40.02±0.98
4	386.05±9.89	325.34±8.71	6.80±0.84	9.44±0.11	19.83±1.11	39.86±0.67
5	384.40±17.31	338.37±2.56	9.29±0.67	9.07±0.40	22.03±1.13	35.57±0.69
6	387.77±11.23	402.53±9.30	9.28±0.36	11.92±0.67	19.11±1.93	41.08±0.91
7	406.91±13.74	430.78±14.86	10.48±0.77	9.51±0.22	21.32±4.20	40.53±1.26
8	359.03±17.34	374.30±6.10	9.16±0.53	10.07±0.47	21.45±0.64	40.55±0.91
9	382.70±9.38	367.18±16.11	9.15±0.29	9.07±0.44	22.39±0.47	41.57±0.08

T a b l e 6. Chemical composition of the raw materials

Raw material	Crude protein	Ash	Crude fibre	NDF	ADF	HCEL	CEL	ADL	IDF	SDF	TDF
	(% d.m.)										
WF	10.24 ±0.01	0.56 ±0.002	0.08 ±0.01	1.02 ±0.08	0.26 ±0.05	0.75	0.21	0.05 ±0.02	2.23 ±0.21	3.25 ±0.03	5.48
PHS	15.58 ±0.09	4.86 ±0.09	32.77 ±0.09	50.12 ±0.16	43.03 ±0.21	7.09	42.75	0.08 ±0.03	63.26 ±0.41	7.43 ±0.17	70.69
PHC	8.05 ±0.07	3.05 ±0.03	53.13 ±0.21	73.76 ±1.76	66.54 ±0.44	7.22	66.41	0.13 ±0.03	86.97 ±0.43	6.32 ±0.21	93.29

11.35% d.m., and breads with 2.5-10% content of small-grained pea hulls had protein content from 11.62 to 11.8% d.m. (Table 7). The protein content of white breads available on the Lublin market varied from 8.14 to 9.94% d.m. (Kasprzak and Rzedzicki, 2009).

It is commonly assumed that bread is a good source of dietary fibre. This is not true of the traditional breads made of whole-meal flour. In the breads under study the content of structural components was examined with the Wendee method, the detergent method, and the enzymatic method.

The content of crude fibre, both in the raw materials and in the breads (crust, crumb), was lower than the content of acid-detergent fibre (ADF) constituting the sum of cellulose and lignin fractions (Tables 6, 7). For the control bread, crude fibre content levels were recorded at up to 0.18% d.m., and ADF content in the crumb at 0.39% and in the crust at 0.55% d.m. (Table 7). Increase in the share of pea hulls in the mixture with wheat flour from 2.5 to 10% caused an increase in the content of crude fibre, NDF, ADF, fractions of HCEL, CEL and ADL, both in the crust and in the crumb of the breads (Table 7).

Notably higher amounts of the structural components were obtained in determinations with the enzymatic method. The dominant fibre fraction in all the breads was insoluble fibre. The content of IDF in the control bread was 6.38% d.m. The application of only 5% of pea hulls, whether fine- or coarse-fragmented, caused the IDF content in the breads to double (Fig. 1). It should be kept in mind that such a bread is characterized by quality and sensory features similar to those of the control bread. In breads with the 10% content of coarse pea hulls the content of total dietary fibre TDF was found to be above 21% d.m., and in those with 10% share of the small-grained pea hulls the TDF content was 17.7%. Such levels of TDF content were noted only in the case of two assortments of dark bread available on the Lublin market (Rzedzicki and Kasprzak, 2009).

The study showed that pea hulls in amounts of up to 10% can be successfully used as a component in baking white breads with increased content of dietary fibre and with features very similar to those of traditional wheat bread. At all stages of the technological process no major differences were noted with relation to the traditional recipe based on wheat flour alone.

T a b l e 7. Chemical composition of the crust and crumb

Sample No.	Crude protein	Ash		Crude fibre		NDF		ADF		HCEL		CEL		ADL	
		crust	crumb	crust	crumb	crust	crumb	crust	crumb	crust	crumb	crust	crumb	crust	crumb
	(% d.m.)														
1	11.35 ±0.02	1.61 ±0.06	1.68 ±0.02	0.18 ±0.02	0.11 ±0.01	4.89 ±0.001	1.56 ±0.01	0.55 ±0.02	0.39 ±0.02	4.33	1.17	0.43	0.31	0.12 ±0.01	0.08 ±0.02
2	11.62 ±0.03	1.66 ±0.01	1.75 ±0.01	1.07 ±0.05	0.94 ±0.05	6.53 ±0.31	2.75 ±0.23	1.77 ±0.15	1.64 ±0.09	4.76	1.23	1.63	1.52	0.14 ±0.02	0.12 ±0.03
3	11.72 ±0.14	1.84 ±0.05	1.87 ±0.01	1.97 ±0.09	1.76 ±0.06	7.87 ±0.12	3.95 ±0.09	3.06 ±0.24	2.62 ±0.06	4.81	1.33	2.90	2.48	0.16 ±0.04	0.14 ±0.01
4	11.73 ±0.16	1.97 ±0.05	2.01 ±0.04	2.67 ±0.19	2.52 ±0.16	9.91 ±0.86	5.50 ±0.07	3.96 ±0.07	3.59 ±0.03	5.95	1.91	3.77	3.44	0.19 ±0.02	0.15 ±0.01
5	11.8 ±0.005	2.10 ±0.02	2.17 ±0.05	3.61 ±0.17	3.50 ±0.17	11.64 ±0.01	6.97 ±0.22	5.14 ±0.14	4.63 ±0.17	6.50	2.34	4.92	4.47	0.22 ±0.03	0.16 ±0.02
6	11.33 ±0.03	1.67 ±0.01	1.69 ±0.004	2.74 ±0.33	1.37 ±0.08	6.81 ±0.04	3.62 ±0.11	2.44 ±0.18	1.81 ±0.08	4.37	1.81	2.29	1.68	0.15 ±0.01	0.13 ±0.04
7	11.19 ±0.004	1.74 ±0.02	1.76 ±0.08	3.44 ±0.16	2.84 ±0.09	9.55 ±0.07	5.31 ±0.04	3.97 ±0.17	3.21 ±0.20	5.57	2.09	3.78	3.06	0.19 ±0.04	0.15 ±0.02
8	11.12 ±0.004	1.78 ±0.01	1.81 ±0.02	4.17 ±0.23	4.20 ±0.23	11.57 ±0.62	7.21 ±0.01	5.71 ±0.03	4.90 ±0.23	5.86	2.31	5.50	4.73	0.21 ±0.01	0.17 ±0.02
9	10.82 ±0.04	1.87 ±0.02	1.95 ±0.03	5.38 ±0.26	5.79 ±0.32	13.14 ±0.37	8.76 ±0.01	7.02 ±0.02	5.70 ±0.14	6.12	3.06	6.78	5.50	0.24 ±0.03	0.20 ±0.04

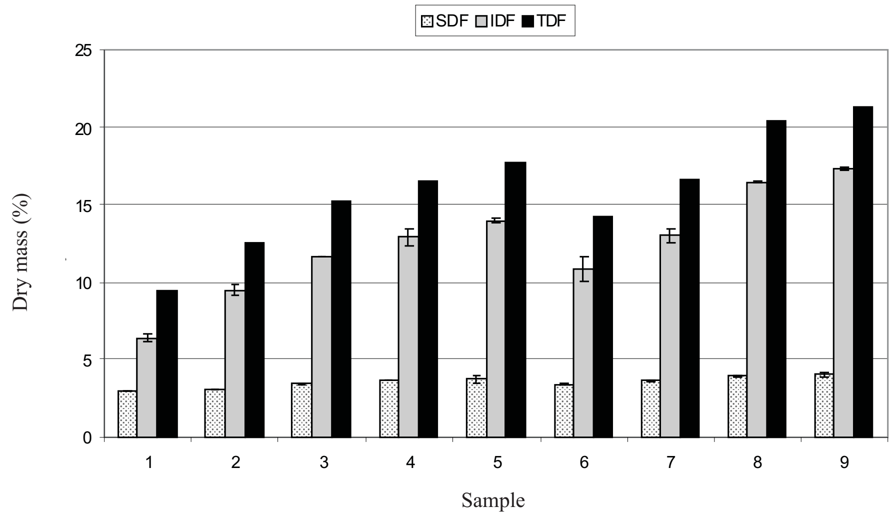

Fig. 1. Content of soluble dietary fiber (SDF), insoluble dietary fiber (IDF) and total dietary fiber (TDF) in the bread.

CONCLUSIONS

1. Pea hulls can be a valuable component in the production of high-fibre white bread with quality and sensory features analogous to those of traditional white wheat bread.

2. Application of the pulse component caused an increase in bread yield and a decrease in the oven loss and total baking loss.

3. Higher marks in sensory evaluation and better physical properties were obtained for breads with a content of small-grained pea hulls (PHS).

4. The breads under study were characterized by very low values of the water solubility index (WSI).

5. Introduction of just 5% admixture of pea hulls in the recipe permits doubling of the content of dietary fibre in bread.

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