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Effect of bath temperature and soaking time on the dynamics of water holding capacity of everlasting pea-wheat extrudates

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A b s t r a c t. The paper presents the results of a study on the effect of soaking time and water bath temperature on the dynamics of hydration of everlasting pea-wheat extrudates. The extrudates were produced with variable raw materials composition; the shares of the leguminous material (everlasting pea whole meal) and cereal material (wheat whole meal) were 35, 50 and 65%, respectively. Other variable factors applied included three levels of raw material moisture, of 18, 21 and 24%, and two profiles of extruder barrel temperature distribution - 90/120/150/140/130°C and 110/140/180/170/130°C. The study of the process of extrusion was conducted by means of a twin-screw extrusion-cooker type 2S-9/5, using a die of diameter of 3x6 mm and screw rotation speed of 75 r.p.m. It was demonstrated that the adopted ranges of process parameters permit stable operation of the extruder and obtainment of good quality products. As samples with a high content of legumes are difficult to hydrate, a study of the dynamics of water absorption by those extrudates was performed. It was shown that increase in the soaking time up to 90 min resulted in unsatisfactory improvement of the amount of water absorbed by the tested samples of everlasting pea-wheat extrudates. Also examined was the effect of varied water temperature at constant soaking time of 15 min. When the water temperature was increased from 20 to 70-80°C, the amount of water absorbed by all the tested extrudates increased, irrespective of their raw material composition and of the process parameters. Further increase of water temperature resulted in a drop of the water holding capacity in all of the samples analysed.

K e y w o r d s: everlasting pea, wheat, extrusion, water holding capacity

INTRODUCTION

Leguminous plants consumption in Poland is very low and varies around the level of 3-6 g per person per day. Dieticians recommend considerably higher level of consumption, of about 10-12 g per person per day (Lesisz, 1997; Troszyńska *et al*., 1997). From among seeds of leguminous plants we consume mainly peas, beans, soybean and lentil. Everlasting pea is an interesting plant which may have a broad application in food production (Rzedzicki and Sobota, 1999). In Poland it has been grown for a long time as a vegetable, especially in the region of Podlasie (Dziamba, 1997; Rybiński *et al*., 2006; Rzedzicki *et al*., 1997). The seed of everlasting pea is characterized by the highest protein content among the polish leguminous plants, a very high content dietary fibre, oligosaccharides and biologically active compounds, and by attractive taste values (Khokhar *et al*., 1996; Lisiewska *et al*., 2003; Monsoor and Yusuf, 2002; Rybiński *et al*., 2006). Very interesting feature of Polish varieties of everlasting pea is a very low level of β – N-oxalyl – L – α, β -diaminopropionic acid (β- ODAP) and α – N-oxalyl – amino – L-alanine (BOAA) (Grela *et al*., 1997); so there is no risk of lathyrism danger. Particular note should be given to the bright colouring of cotyledons that do not darken during thermoplastic treatment of raw materials. This creates considerable potential for the application of the seed in the production of a variety of extruded products (Rzedzicki, 1997; Rzedzicki and Zarzycki, 2005). Everlasting pea can be used both in the production of typical snack crisps with a content of corn grits and in the production of vegetarian lunch meals. Immediately prior to consumption, extruded lunch meal products with a high content of leguminous material must be subjected to further culinary treatment at home, consisting in hydration and frying in hot oil. Everlasting pea-wheat extrudates with a high protein content are characterized by a compact and hard structure, and thus do not absorb water easily (Rzedzicki and Sobota, 1999). Those features of the products cause an extension of the time of culinary treatment and preparation of a ready meal.

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The aim of the presented study was to examine the effect of selected parameters of the process of extrusion, and of the temperature and time of sample soaking, on the water holding capacity of extruded everlasting pea-wheat meal products.

MATERIALS AND METHODS

The raw materials used in the study included whole meal of sowing everlasting pea (*Lathyrus sativus*), cv. Derek, and whole meal of high-gluten wheat, cv. Henika. The raw materials were grinded using a universal impact grinder type H-111/3 until obtaining the required level of mean diameter and share rate of fractions <0.5 mm (Table 1). The chemical composition of the raw materials used was also determined; the results are given in Table 2. In the samples tested, the water content was determined with the dryer method (AACC, Method 44-15A), crude protein content with the Kjeldahl

T a b l e 1. Sieve analysis of components

Fraction (mm)	Everlasting pea meal (%)	Wheat meal (%)
> 1.6	0	12.5
1.6 - 1.2	1.8	22.3
1.2 - 1.0	10.3	16.4
1.0 - 0.8	21.2	12.3
0.8 - 0.5	27.1	14.7
0.5 - 0.265	19.2	12.9
< 0.265	20.4	8.9
Σ of fractions <0.5	39.6	21.8
Mean diameter (mm)	0.62	0.96

T a b l e 2. Chemical composition of raw materials and extrudes

No.	N-free extr.	Crude protein	Fat	Ash	Crude fiber	NDF	ADF	HCEL	CEL	ADL	IDF	SDF	TDF
	(% d.m.)												
Everlasting pea meal													
	61.65	28.00	1.14	3.41	5.80	22.20	7.90	14.30	7.82	0.08	28.96	4.34	33.30
Wheat meal													
	75.42	16.28	1.31	3.74	3.25	14.71	4.41	10.30	3.30	1.11	14.74	3.69	18.43
Mixture sample													
1	72.85	19.96	0.54	3.64	3.01	11.22	4.79	6.43	4.16	0.63	13.68	3.55	17.23
2	70.48	22.09	0.40	3.62	3.41	10.84	5.55	5.29	4.97	0.58	14.71	4.01	18.72
3	68.81	23.68	0.34	3.59	3.58	10.46	6.30	4.16	5.86	0.44	16.12	4.77	20.89
4	73.04	19.45	0.91	3.64	2.96	11.29	4.68	6.61	4.00	0.68	13.37	2.35	15.72
5	70.38	22.12	0.62	3.62	3.26	10.90	5.63	5.27	5.17	0.46	14.16	2.69	16.85
6	68.30	23.85	0.51	3.57	3.77	10.12	6.59	3.53	6.19	0.40	15.16	3.72	18.88
7	72.68	19.99	0.46	3.65	3.22	11.96	4.99	6.97	4.33	0.66	14.30	3.85	18.15
8	70.91	21.89	0.33	3.60	3.27	10.30	5.26	5.04	4.78	0.48	15.30	4.19	19.49
9	68.70	23.71	0.29	3.52	3.78	10.12	6.16	3.96	5.82	0.34	16.05	4.30	20.35
10	72.43	19.86	0.88	3.66	3.17	12.55	5.01	7.54	4.36	0.65	14.07	4.28	18.35
11	70.36	22.10	0.61	3.65	3.28	11.84	5.59	6.25	5.13	0.46	15.19	4.75	19.94
12	68.60	23.84	0.45	3.58	3.53	11.41	6.40	5.01	6.09	0.31	15.60	5.61	21.21
13	73.60	19.32	0.69	3.61	2.78	11.04	4.87	6.17	4.28	0.59	14.07	2.82	16.89
14	70.85	21.84	0.49	3.59	3.23	10.82	5.71	5.11	5.28	0.43	14.95	4.52	19.47
15	68.52	23.45	0.47	3.53	4.03	10.78	6.28	4.50	5.95	0.33	15.84	5.35	21.19
16	72.95	19.80	0.67	3.67	2.91	12.12	4.82	7.30	4.11	0.71	15.28	4.52	19.80
17	70.82	22.07	0.46	3.62	3.03	11.84	5.57	6.27	5.05	0.52	15.46	4.86	20.32
18	68.84	23.67	0.34	3.55	3.60	11.60	6.60	5.00	6.25	0.35	16.97	5.09	22.06

method (AOAC, Method 981.10) – (N x 6.25), crude fat content with the Soxhlet method (AOAC, Method 963.15), crude fibre content with the Wendee method (AACC, Method 32-10), as well as the crude ash content (AACC, Method 08-01). From difference of dry matter and the above, N-free extract was calculated. The fractional composition of dietary fibre was determined with the detergent method of Van Soest (neutral-detergent fibre – NDF, acid-detergent fibre – ADF, cellulose – CEL, hemicellulose – HCEL and acid-detergent lignin – ADL) and with the enzymatic method (AOAC, Method 991.43; AACC, Method 32-07; AACC, Method 32-21; AOAC, Method 985.29; AACC, Method 32-05), using Megazyme enzymes and methodological procedures. The determinations included total dietary fibre – TDF, insoluble dietary fibre – IDF, and soluble dietary fibre – SDF. In the samples studied also the water absorption (WAI) was determined, with the centrifugal method (AACC, 2000), and the content of soluble components of dry mass (WSI), according to the AACC Method 56-20 as modified by Rzedzicki *et al*. (2004). The chemical analyses were made in three replications, and determinations of WSI and WAI in five. The measurement results were used to calculate the mean values, standard deviations, and coefficients of variation. If the values of the coefficient of variation exceeded the limits of error estimated for a given method, the results were rejected and analyses were repeated until the correct scatter of results was obtained.

The above raw materials were used to prepare mixtures, in accordance with the model of the experiment (Table 3). The share of everlasting pea was variable, at 35, 50 and 65%, respectively. The mixtures were moistened to the required level (18, 21, and 24%), homogenized in a drum mixer and conditioned for 12 h at room temperature to ensure correct water diffusion in the material. Samples prepared in that manner were fed into the 2S-9/5 twin-screw extruder (Metalchem – Gliwice) for thermoplastic treatment. Two profiles of barrel temperature distribution were applied – 90/120/150/140/130°C and 110/140/180/170/130°C. The extruder used in the experiments was equipped with a die of 3x6 mm in diameter. Constant screw speed of 75 r.p.m. was applied throughout.

Analysis of water absorption of everlasting pea-wheat extrudates was also performed, as an operation preceding frying. The water absorption capacity was studied at water bath temperature increasing at 10°C increments within the range from 20 to 90°C and at varied soaking time of 5, 10, 15, 30, 45, 60, 75, and 90 min. For the tests, portions of 10 g of extrudate were taken, flooded with water at required temperature, and left to soak in the water bath for the required time. Next the samples were screened through a 20 mesh sieve and weighed. The water holding capacity of the samples was calculated as the ratio of water absorbed by the extrudate to the dry weight of the sample tested, and expressed as percentage values. The tests were performed in 5 replications.

T a b l e 3. Model of experiments

Mixture sample	Everlasting pea meal (%)	Wheat meal (%)	Moisture (%)	Barrel temperature profile (°C)
1	35	65	18	90/120/150/140/130
2	50	50		
3	65	35		
4	35	65	21	
5	50	50		
6	65	35		
7	35	65	24	
8	50	50		
9	65	35		
10	35	65	18	110/140/180/170/130
11	50	50		
12	65	35		
13	35	65	21	
14	50	50		
15	65	35		
16	35	65	24	
17	50	50		
18	65	35		

RESULTS AND DISCUSSION

The study showed that the adopted operation parameters of the extruder and the variable ranges of the raw material composition permitted stable operation of the extruder. No slippage of extruded material was observed, nor seizing of the extruder or raw material sticking to the working elements. Thus, proper selection of process parameters guaranteed stable operation of the extruder and obtainment of uniform products.

The application of the counter-rotating twin-screw extrusion-cooker permitted the production of lunch meals on the basis of everlasting pea that is characterized not only by a high content of proteins (even above 23%) but also of total dietary fibre (even up to 22%) (Table 2). The chemical composition of the extrudates was mainly dependent on the composition of the raw materials mixture and on the parameters of the extrusion process, especially in the case of the dietary fibre fractions.

The everlasting pea-wheat extrudates produced, characterized by a high content of proteins (19.32-23.85% d.m., Table 2), had a compacted and hard structure. Studies performed so far showed that samples with such a high content of leguminous material take a long time to absorb water (Rzedzicki and Fornal, 1999). With the application of the eluate method, the soaking time being 15 min, the values of water holding capacity obtained for the samples tested were within the range from 56.20 to 93.40% d.m. (Table 4). Such low amounts of absorbed water result in considerable extension of the time of culinary treatment; therefore, search for more effective conditions of water absorption was necessary.

T a b l e 4. Water Solubility Index (WSI) and Water Absorption Index (WAI) of raw materials and extrudates

Sample	WSI (% d.m.)	WAI centrifugal method (% d.m.)	WAI reflux method (% d.m.)
Everlasting pea meal	22.65	213	not measured
Wheat meal	1	202	not measured
Mixture sample			
1	12.04	579.34	73.60
2	13.75	549.20	74.00
3	17.68	466.39	80.20
4	10.20	559.54	58.60
5	12.76	548.89	66.60
6	15.01	475.36	64.60
7	11.99	641.06	69.60
8	14.87	594.20	66.80
9	15.45	487.11	69.40
10	11.22	515.86	56.20
11	13.42	465.40	68.40
12	18.96	419.45	76.40
13	12.23	555.46	61.00
14	13.71	515.06	63.60
15	16.69	443.93	67.80
16	11.10	594.16	73.80
17	13.58	519.31	72.60
18	19.11	433.68	93.40

Extension of the extrudate soaking time from 5 to 90 min permitted a certain improvement of the water holding capacity of the extrudates. Increase in the amount of absorbed water was observed for all the samples tested, irrespective of the raw material composition and of the extrusion process parameters *ie* the moisture of the mixture treated and the profile of barrel temperature distribution (Fig. 1). In the case of samples containing 35% of everlasting pea whole meal, obtained at raw material moisture of 21% and extruder cylinder temperature distribution profile of 90/120/150/140/130°C, the amount of absorbed water increased from 78.33% d.m. to 149.33% d.m. (Fig.1a, sample No. 4). In the case of extrudates containing 50% of everlasting pea whole meal and 50% of wheat whole meal, obtained at raw material moisture of 21% and barrel temperature distribution profile of 90/120/150/ 140/130°C (Fig. 1b, sample No. 5), the extension of soaking time to 90 min resulted in an increase in the amount of absorbed water by 93.33% d.m. The lowest increase in water absorption capacity, 56.34% d.m., was recorded for samples containing everlasting pea and wheat whole meal at the ratio of 1:1, moistened to the level of 18%, subjected to treatment at temperatures of 90/120/150/140/130°C (Fig. 1, sample No. 2). A similar orientation of changes was also observed in other studies. Rzedzicki and Sobota (1999) showed that the level and rate of water absorption by corn-pea extrudates was mainly determined by the sample soaking time, and not by the composition of the mixture subjected to extrusion. In the case of extrudates with 2.5-7.5% admixture of pea hulls, the water holding capacity was within the range of approx. 440-460% (Rzedzicki and Sobota, 2006). The application of the counter-rotating twin-screw extrusion-cooker type 2S-9/5 permitted the production of extrudates containing up to 80% of pea hulls, but as the content of the leguminous material increased a very strong reduction was observed in the value of WAI, from 622.4 to 119.6% (Rzedzicki *et al*., 2004).

The application of three levels of raw material moisture, of 18, 21 and 24% (Fig. 1a,b,c) did not result in any changes in the water holding capacity of the extrudates. Slight differences in the amount of absorbed water were observable only for soaking times up to 15 min. In studies on strongly expanded extrudates with a content of other raw materials, diverse effects of the moisture content of the extruded material on the water absorption capacity of the extrudates were observed. In the case of corn-oats extrudates, an increase in the value of WAI was observed with increasing raw material moisture (Rzedzicki *et al*., 2000). For corn extrudates with a content of pea hulls, increase in the moisture of the extruded mixture was accompanied by a drop in the value of WAI (Rzedzicki and Sobota, 2006).

Like the moisture of the extruded mixture, the temperature of the process did not have any significant effect on the results of the water holding capacity of hard everlasting pea-wheat extrudates (Fig. 1). The results of water absorption of extrudates formed at process temperatures of 90/120/150/140/130°C (samples 1-9) and those obtained at 110/140/180/170/130°C (samples 10-18) fell within similar ranges.

It should be kept in mind that soaking in water constituted only the preparation of the semi-product for further culinary treatment, hence the soaking time of 90 min is much too long and cannot be used in practice. Therefore, the possibility of increasing the bath temperature was studied. In the

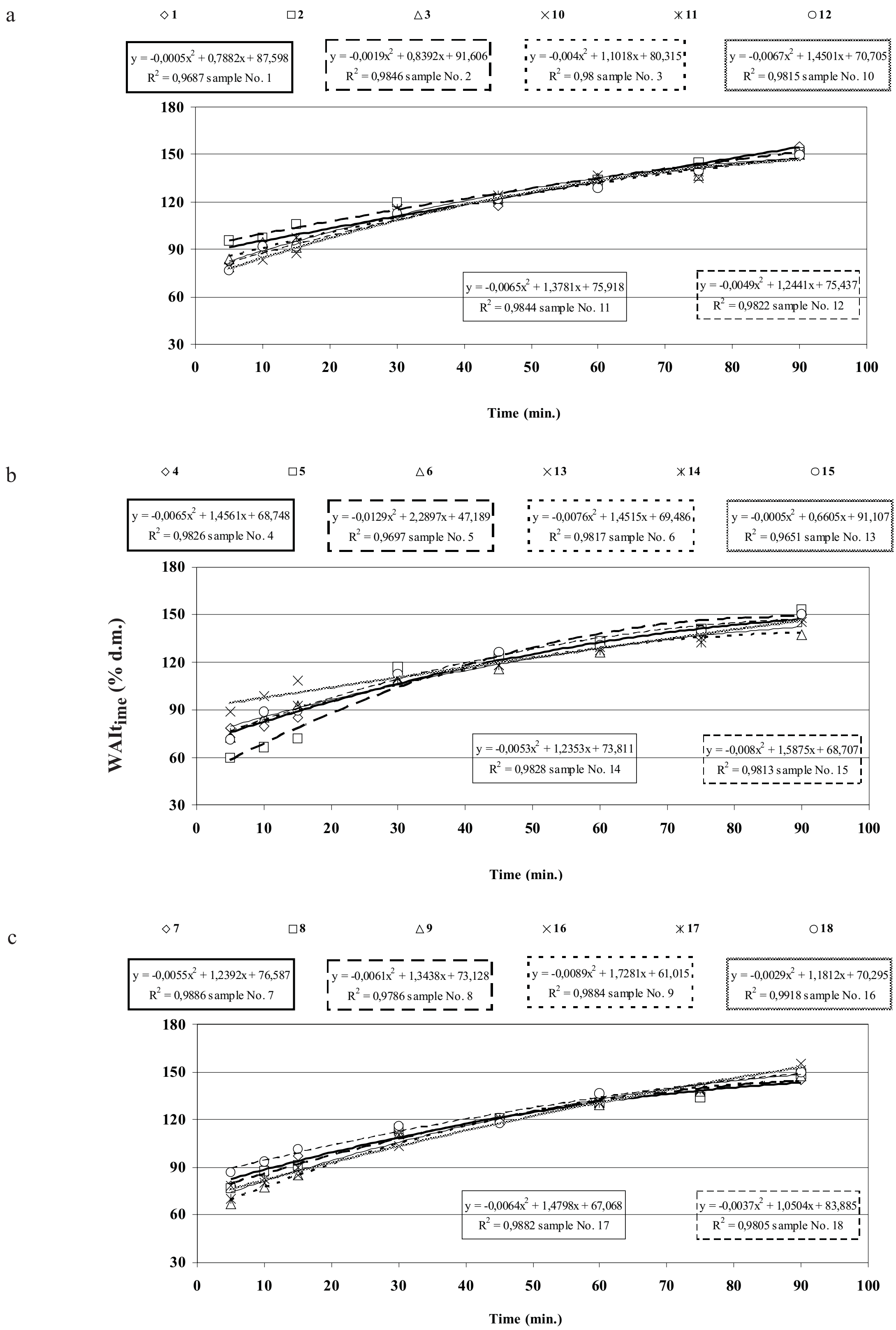

Fig. 1. The influence of soaking time on the water absorption index (WAI_{time}); moisture: a – 18, b – 21, and c – 24%; water temperature - 20°C.

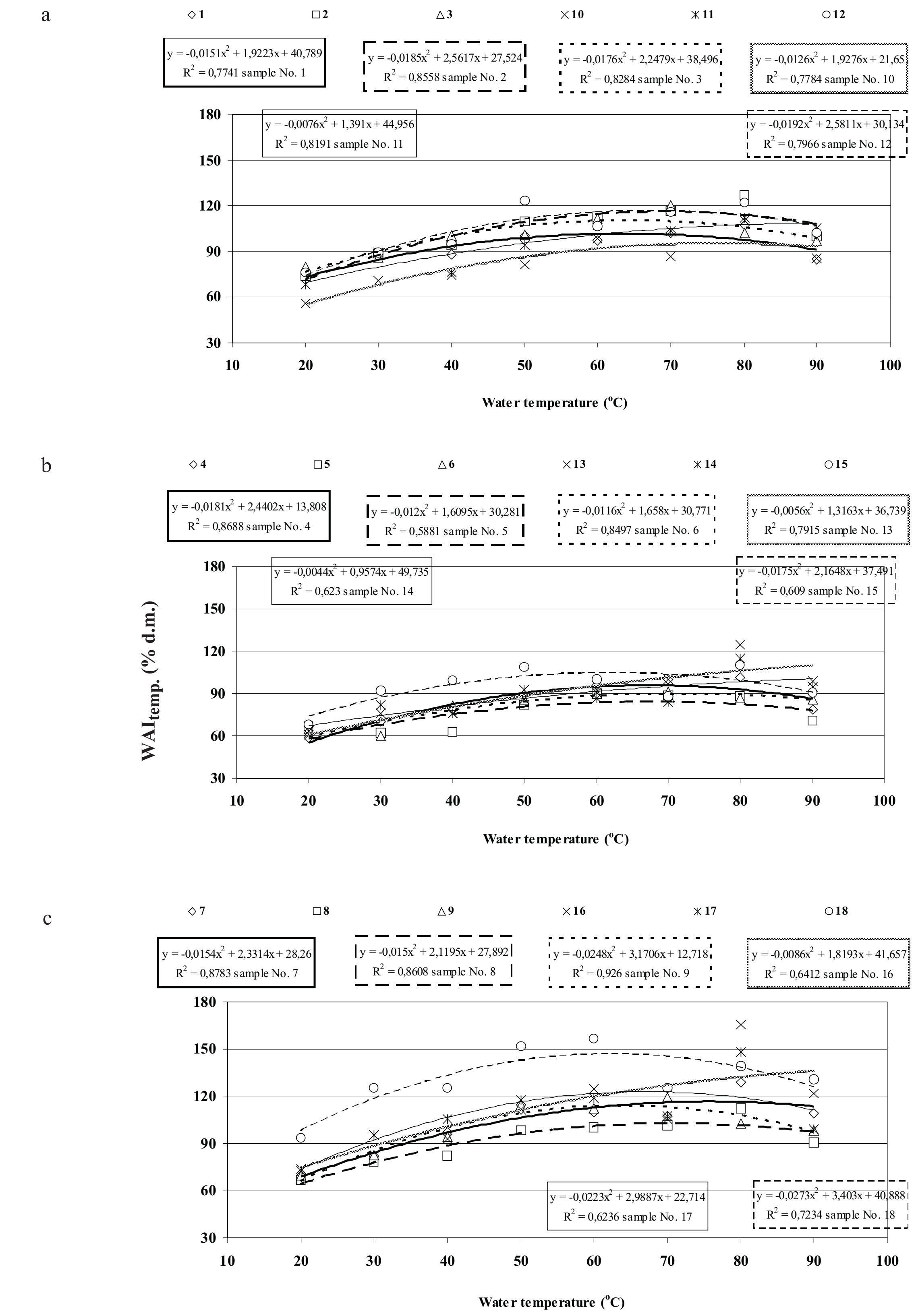

Fig. 2. The influence of water bath temperature on the water absorption index (WAI_{time}); moisture: a – 18, b – 21, and c – 24%; time - 15 min.

experiment a constant soaking time of 15 min was applied. The use of water of increased temperature (Fig. 2) resulted in an improvement of water holding capacity of all the extrudates under study, irrespective of their raw material composition and extrusion process parameters applied. The ability of the extrudates to absorb water increased with increasing water temperature, but only within the range from 20 to 70-80°C. Once the temperature of 70-80°C was exceeded, a notable decrease in water holding capacity was observed in all the everlasting pea-wheat products under analysis. When water of 20°C was used, the water holding capacity of the extrudates varied from 56.2% d.m. (35% of everlasting pea whole meal, 18% moisture, barrel temperature distribution profile of 110/140/180/170/130°C; sample No. 10) to 93.40% d.m. (65% of everlasting pea whole meal, 24% moisture, barrel temperature distribution profile of 110/140/180/170/130°C; sample No. 18). Water temperature increase to 70-80°C, with 15 min soaking time, resulted in an improvement of water holding capacity of all the samples tested. The maximum amount of absorbed water, 165.33% d.m., was recorded for extrudates with 35% content of leguminous material and 65% of wheat whole meal, obtained at the highest levels of material moisture and process temperature (Fig. 2c, sample No. 16).

With variable temperature of water used for the soaking, changes in raw material composition and extrusion parameters did not exhibit any significant effect on the results of water absorption tests. Variation in the level of moisture (18-24%) and profile of barrel temperature distribution (90/120/150/140/130°C and 110/140/180/170/ 130°C) resulted in a similar range of values (Fig. 2). The level and rate of water absorption of the extrudates were determined primarily by the water bath temperature and, to a lesser extent, the time of soaking.

The material mixture composition applied in the study, the moisture of the raw materials, and the profiles of cylinder temperature distribution did not create products that would absorb water easily. It is, therefore, necessary to conduct further studies aimed at the introduction of admixtures that would preserve the compact structure of the product while permitting water penetration into the extrudates.

CONCLUSIONS

1. Whole meal of everlasting pea is an excellent component introducing vegetable proteins and dietary fibre, including also soluble dietary fibre fraction.

2. Application of a counter-rotating twin-screw extrusion-cooker (2S-9/5) in the study permitted the production of high-quality products for use in vegetarian lunch dishes with leguminous material content from 35 to 65%.

3. The level of everlasting pea whole meal, the moisture of the extruded mixture and the profile of cylinder temperature distribution did not have any significant effect on water absorption of the extrudate.

4. The amount of water absorbed by the extrudate was determined primarily by the water bath temperature and the time of soaking.

REFERENCES

AACC- Approved Methods, **2000.**

Dziamba S., 1997. The biology and agrotechnics of chicking vetch (in Polish). Proc. Int. Symp. '*Lathyrus sativus* – cultivation and nutritive value in animals and humid', June 9-10, Lublin-Radom, 27-33.

Grela E.R., Truchliński J., Rzedzicki Z., Pallauf J., and Winiarska A., 1997. Influence of different conditions of extrusion on the nutritional factors content in flat pea (*Lathyrus sativus*) seeds (in Polish). Proc. Int. Symp. '*Lathyrus sativus* – cultivation and nutritive value in animals and humid', June 9-10, Lublin-Radom, 80-85.

Khokhar S., Frias J., Price K.R., Fenwick G.R. and Hedley C.L., 1996. Physico–chemical characteristics of khesari dhal (*Lathyrus sativus*): changes in α-galactosides, monosaccharides and disaccharides during food processing. J. Sci. Food Agric., 70, 4, 487-492.

Lesisz M., 1997. Application of everlasting pea in humid nutrition (in Polish). Proc. Int. Symp. '*Lathyrus sativus* – cultivation and nutritive value in animals and humid', June 9-10, Lublin-Radom, 154-160.

Lisiewska Z., Korus A., and Kmiecik W., 2003. Changes in chemical composition during development of grass pea (*Lathyrus sativus L.*) seeds. Food, 47, 6, 391-396.

Monsoor M.A. and Yusuf H.K.M., 2002. In vitro protein digestability of lathyrus pea (*Lathyrus sativus*), lentil (*Lens culinaris*), and chickpea (*Cicer arietinum*). Int. J. Food Sci. Technol., 37, 1, 97-100.

Rybiński W., Błaszczak W., and Fornal J., 2006. Seed microstructure and genetic variation of characters in selected grass-pea mutants (*Lathyrus sativus L.*). Int. Agrophysics, 20, 317-326.

Rzedzicki Z., 1997. Extrusion cooking technolgy of everalsting pea (*Lathyrus sativus*) (in Polish). Proc. Int. Symp. '*Lathyrus sativus* – cultivation and nutritive value in animals and humid', June 9-10, Lublin-Radom, 95-103.

Rzedzicki Z., Lipiec A., and Milczak M., 1997. Extrusion-cooking of the 'Everlasting pea' (*Lathyrus sativus*) for use in vegetarian foods. Eng. Food, Sheffield Academic Press, H29-H32.

Rzedzicki Z. and Fornal J., 1999. Influence of process parameters on the physical properties and microstructure of everlasting pea (*Lathyrus sativus*) extrudate. Int. Agrophysics, 13, 109-117.

Rzedzicki Z. and Sobota A., 1999. The investigation of hydration process of pulses extrudate (in Polish). Advances of Technique of Food Proc., 1-2, 17-22.

Rzedzicki Z. and Sobota A., 2006. Study on the process of single-screw extrusion-cooking of mixtures with a content of pea hulls. Int. Agrophysics, 20, 327-336.

Rzedzicki Z., Sobota A., and Zarzycki P., 2004. Influence of pea hulls on the twin screw extrusion-cooking process of cereal mixtures and the physical properties of the extrudate. Int. Agrophysics, 18, 73-81.

Rzedzicki Z., Szpryngiel B., and Sobota A., 2000. Estimation of some chosen physical properties of extrudates obtained from corn semolina and oat bran mixtures. Int. Agrophysics, 14, 233-239.

Rzedzicki Z. and Zarzycki P., 2005. A study on the technology of extrusion cooking of mixtures with a share of everlasting pea and oat meal (in Polish). Acta Agrophysica, 126, 515-528.

Troszyńska A., Honke J., Milczak M., and Kozłowska H., 1997. Bioactive compouns in lathyrus sativus seeds (*Lathyrus sativus L.*) and lentil seeds (*Lens culinaris* Medik) (in Polish). Proc. Int. Symp. '*Lathyrus sativus* – cultivation and nutritive value in animals and humid', June 9-10, Lublin-Radom, 86-89.