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DIETARY FIBRE CONTENT AND ITS FRACTIONAL COMPOSITION IN CABBAGE AS AFFECTED BY CULTIVAR EARLINESS AND SAUERKRAUT STORAGE PERIOD

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Summary

The aim of the study was to determine the dietary fibre content and its fractional composition in white head cabbage cultivars of different maturity earliness and also in fermented cabbage (sauerkraut) after several months of storage, as well as the level of fibre and its composition in sauerkraut in relation to the method of fermentation.

It was found that there were significant differences in fibre content and its fractions composition among the white cabbage cultivars studied. The early cultivar Tekila F_1, had a lower total fibre content and smaller cellulose and pectin fractions than the later-maturing cultivars, Tolerator F_1 and Agresor F_1. The fermented cabbage, as compared with the raw material, contained a significantly larger cellulose fraction, a significantly reduced pectin fraction, slightly reduced amounts of hemicelluloses, and a similar amount of lignin. There was no obvious effect of inoculating cabbage with starter cultures containing strains of *Lactobacillus plantarum* on the level of fibre and its fractions in the resulting sauerkraut in comparison with the traditionally fermented cabbage. Water-absorbing capacity of cabbage fibre depended on the cultivar, the length of sauerkraut storage period and fermentation method. The fibre of the early cabbage variety had a significantly lower water-binding capacity than the fibre of the later-maturing cultivars. Rehydration capacity of dried sauerkraut increased for up to 30 days from the end of fermentation, with longer storage period having no longer any effect on the levels of water absorption. Water-holding capacity of the fibre in the sauerkraut produced with the addition of a starter culture was lower than that of the fibre of the traditionally fermented cabbage over the entire storage period of the fermented sauerkraut samples.

key words: white head cabbage, raw, sauerkraut, storage, dietary fibre

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INTRODUCTION

The white head cabbage, both fresh and fermented, is a very valuable vegetable because of its nutritional and health-enhancing properties. These properties result from a high vitamin C content, and the high levels of phenolic compounds and glucosinolates (Leja *et al.* 2006). The white cabbage is also a rich source of dietary fibre (Cummings 1993, Elkner 2000). The dietary fibre consists of insoluble fractions (cellulose, hemicelluloses, lignin) and soluble fractions (mainly pectins), which are important for the digestive process. These fractions determine the fibre's functional properties and produce different effects in the digestive tract (Eastwood 1992, Hasik *et al.* 1997, Slavin 2001). The insoluble fractions stimulate peristalsis and accelerate the passage of intestinal contents, whereas the soluble fibre reduces the level of cholesterol. The relative amounts of the separate constituents of the dietary fibre in fresh cabbage vary and depend on the cultivar, fertilization and harvest date (Sorensen 1984, Elkner 2000). A considerable effect on the changes in fibre content and the size of its fractions in cabbage is shown by the length of the storage period and the method of processing (Elkner 2002, Wennberg *et al.* 2002). Studies by Elkner & Kosson (1995) had revealed that the fermentation process reduced the fibre content in the late cabbage cultivar Kamienna Głowa.

The various effects that the dietary fibre produces on the functions of the digestive tract are associated not only with its quantity and quality but also with its capacity for water absorbtion (WHC – water-holding capacity) (Górecka *et al.* 1996). This property of the dietary fibre can be substantially affected by processing. According to Korczak *et al.* (1995), the water-absorbtion capacity of vegetable fibres is largely affected by the pH of the environment.

Studies carried out by Beecher (1994) and Verhoeven *et al.* (1997) had revealed an inverse relationship between the consumption of vegetables of the *Brassicacae* family and the risk of incidence of colon cancer. According to Verker *et al.* (2001), the anticarcinogenic effect of brassica vegetables depends on the fibre content and its composition.

High consumption of fresh and fermented cabbage in Poland and the beneficial effect of dietary fibre on human health had created a need for determining the fibre's fractional composition in new white head cabbage cultivars of different maturity earliness and in sauerkraut during its several months of storage. The aim of the present study was also to determine the amount of fibre and its composition in sauerkraut in relation to the method of fermentation.

MATERIAL AND METHODS

The experimental material consisted of three cultivars of white head cabbage with different vegetation periods, all suitable for making sauerkraut. The cultivars included: Tekila F_1 (early, 90 days from planting to harvest), Tolerator F_1 (medium-early, 115 days from planting to harvest), and Agresor F_1 (medium-late, 130 days from planting to harvest). The cultivars originated from a cultivar breeding experiment carried out at Agricultural Schools in Radom in 2004-2006. Fertilization and maintenance procedures had been carried out in accordance with the recommendations for the cultivation of white cabbage.

The harvested cabbage was fermented in containers with a capacity of 10 kg each, in three replications for each cultivar. The amount of table salt (evaporated salt) added to the shredded cabbage was 2.2% by weight. The initial fermentation process proceeded at a temperature of approx. 20°C. After 10 days, when approx. 1% of lactic acid had formed, the cabbage-containing barrels were placed at a temperature of approx. 8°C for further storage.

In 2006, in addition to fermenting cabbage in the traditional way (control), controlled fermentation was also carried out using beneficial cultures of lactic bacteria, so-called starter cultures. An inoculum (Vege-Start starter culture) containing large amounts of *Lactobacillus plantarum* (incubation level of $10^6 \cdot g^{-1}$) was added to the barrels filled with shredded cabbage.

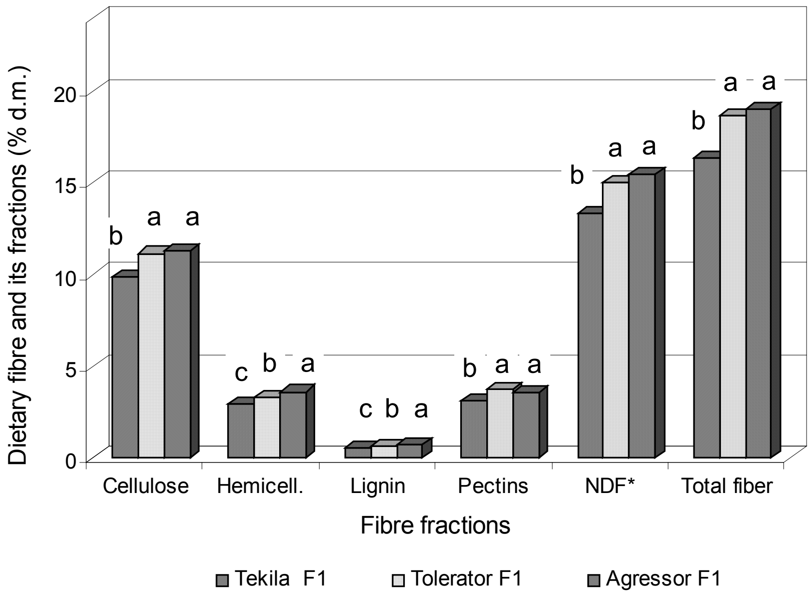
The dietary fibre content, its fractions composition, and the fibre's water-holding capacity (WHC) were determined for the fresh cabbage, the traditional sauerkraut (10, 30, and 90 days after the end of fermentation), and the sauerkraut produced by fermenting cabbage with the addition of Vege-Start starter culture.

The dietary fibre content and its fractional composition were determined using the detergent method described by Goering and Van Soest (1970). It is a method consisting in isolating fibre fractions by means of neutral or acid detergent solutions, which makes it possible to determine the levels of cellulose, hemicelluloses and lignin. Pectins were determined using King's (1987) colorimetric method. The overall amount of pectins and neutral detergent fibre (NDF) was expressed as total fibre. The water-holding capacity of the fibre contained in fresh and fermented cabbage was determined using the method described by Robertson *et al.* (1980).

The results of the analyses of fibre content and its fractions were evaluated statistically using analysis of variance in an independent system. Mean values were compared with Newman-Keuls test at a significance level of P=0.05.

RESULTS AND DISCUSSION

The total fibre content in fresh white cabbage in the three consecutive years of the study was at a similar level and amounted to 18% DW on average. The dominating fraction in the cabbage fibre, around 11%, was that of cellulose. The results presented in Fig. 1 show significant differences in the dietary fibre content and the size of its fractions among the studied cultivars of cabbage. This agrees with the results of earlier studies by Sorensen (1984) and Elkner (2002). The early cabbage variety, Tekila F_1, contained lower amounts of fibre than the later-maturing cultivars, which was associated with lower levels of cellulose and pectins in the fibre of that cultivar. Studies by Wennberg *et al.* (2002), who analysed several cabbage varieties of different maturity earliness, had also shown that the early cultivars had lower levels of fibre and its fractions in comparison with medium-late and late cultivars.

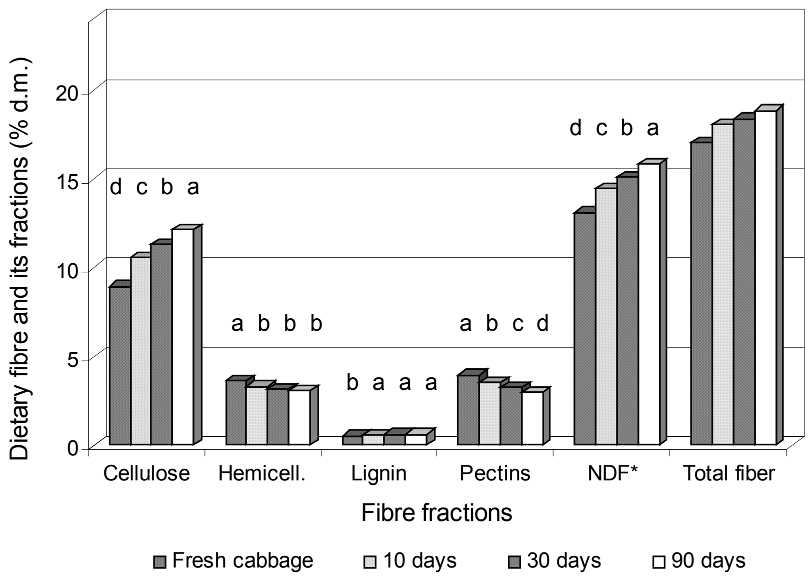


*- NDF – neutral detergent fibre
Note: means marked with the same letters do not differ significantly at P=0.05

Fig. 1. Contents of fibre and its fractions in 3 cultivars of white head cabbage (averages for 3 years)

The fermentation process was found to cause an increase in the NDF content of sauerkraut, which should be thought of as a result of significant quantitative changes in the level of cellulose, and to a small degree in that of hemicelluloses (Fig. 2). However, the pectin fraction was found to have been reduced. On the other hand, there were no marked differences in the size of the lignin fraction between fresh and fermented cabbage. This pattern of changes in the individual fractions of the fibre in sauerkraut had occurred in all three cabbage cultivars throughout the three years of the study.

In the fully-fermented cabbage stored for 90 days the average level of cellulose was found to have increased by an average of 37% in comparison with fresh cabbage, with the corresponding figures for the sauerkraut stored for 10 and 30 days being 18% and 26%, respectively. There was also a marked effect of the length of the sauerkraut storage period on the pectin content. The average losses in the pectin fraction in the sauerkraut stored for 90 days after the completion of fermentation amounted to an average of 24% in comparison with fresh cabbage, whereas those in the sauerkraut stored for 10 and 30 days were 10% and 17%, respectively.



Note: see Fig. 1

Fig. 2. Contents of fibre and its fractions in sauerkraut depending on time of storage (averages for 3 cultivars and 3 years)

It was found that there was a significant combined effect of the cultivar and the length of the storage period on the pectin content in sauerkraut in all the years of the study, and on the NDF content and cellulose content only in 2006 (Table 1). The highest losses in pectin content were found in the sauerkraut made from Tekila F_1 after 90 days of storage – an average of 32% in comparison with fresh cabbage – with those losses amounting to 21% and 18%, on average, for the sauerkraut produced from Tolerator F_1 and Agresor F_1, respectively. Extending the storage period of Tekila F_1 sauerkraut caused the NDF content and the cellulose content to increase (significantly in 2006), whereas in the sauerkraut produced from Tolerator F_1 and Agresor F_1 the levels of these fractions kept increasing only until 30 days after the end of fermentation, and further storage no longer had any effect on their levels (Table 1). Earlier studies by Elkner and Kosson (1995) on the fractional composition of dietary fibre in the cabbage cultivar Kamienna Głowa had also revealed that after fermentation the amounts of the neutral fibre and cellulose increased and those of hemicelluloses decreased.

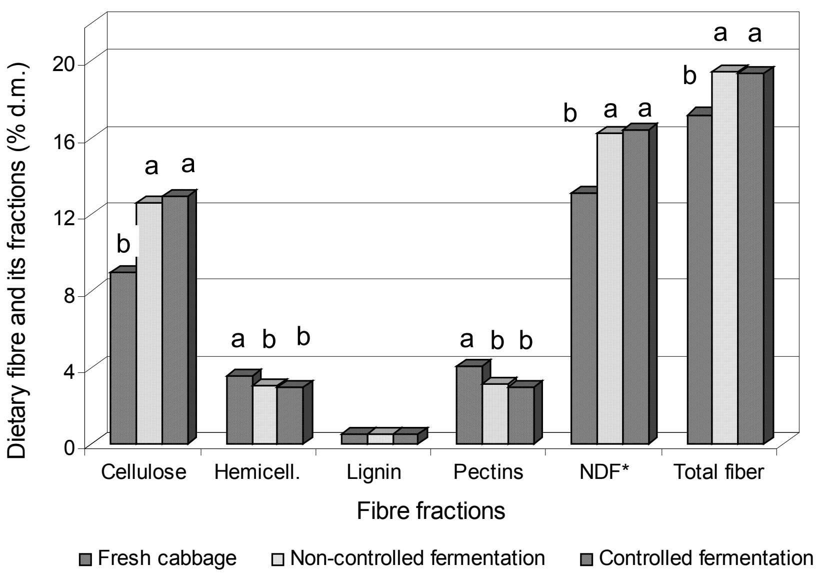
Table 1. The effect of cultivar and time of storage on content of dietary fibre in sauerkraut, (% d.m.), 2006

Cultivar	Period of storage of sauerkraut (days)	Cellulose	Hemi-cellulose	Lignin	Pectins	Neutral detergent fibre (NDF)	Total fibre
Tekila F_1	Raw	7.72 f	3.30	0.43	3.85 b	10.95 f	14.80 e
	10	8.45 e	3.05	0.48	3.58 cd	11.97 e	15.55 de
	30	9.62 d	2.80	0.50	3.08 e	13.10 d	16.18 d
	90	10.48 bc	2.70	0.45	2.40 f	13.88 c	16.28 d
Tolerator F_1	Raw	9.72 d	3.60	0.53	4.32 a	13.25 d	17.57 bc
	10	10.12 cd	3.15	0.55	4.13ab	13.71 cd	17.84 bc
	30	13.35 a	3.02	0.55	3.81 bcd	16.92 a	20.73 a
	90	13.66 a	3.05	0.55	3.41 d	17.26 a	20.67 a
Agresor F_1	Raw	9.57 d	3.85	0.53	4.13 ab	13.12 d	17.25 c
	10	10.78 b	3.75	0.63	3.77 bcd	14.64 b	18.41 b
	30	13.40 a	3.60	0.63	3.56 cd	17.28 a	20.84 a
	90	13.67 a	3.48	0.60	3.63 cd	17.52 a	21.15 a
Means for cultivars	Tekila F_1	9.07 B	2.96 B	0.47 B	3.23 B	12.48 B	15.71 B
	Tolerator F_1	11.72 A	3.21 B	0.56 A	3.92 A	15.30 A	19.22 A
	Agresor F_1	11.86 A	3.67 A	0.60 A	3.77 A	15.64 A	19.42 A
Means for storage time	Raw	9.01 D	3.58 A	0.51	4.10 A	12.47 D	16.57 C
	10	9.78 C	3.32 B	0.55	3.83 B	13.43 C	17.26 B
	30	12.12 B	3.14 BC	0.56	3.48 C	15.75 B	19.23 A
	90	12.60 A	3.08 C	0.54	3.15 D	16.22 A	19.37 A

Note: see Fig. 1
small letters = effect of interaction
capital letters = effect of cultivars and period of storage

The inoculation of cabbage with starter cultures was not found to have an effect on the changes in the levels of cellulose, hemicelluloses, lignin, and pectins in the fermented product in comparison with the levels of these components in the cabbage fermented in the traditional way (Fig. 3). Either method of fermenting cabbage had produced sauerkraut in which there was a significant increase in the size of the cellulose fraction in comparison with the raw material. This may have been caused by the loosening of cell walls and the release of cellulose, and the reduction in the size of the hemicellulose and pectin fractions. One of the more important functional properties of dietary fibre is its water-holding capacity reflecting the fibre's ability to swell. The obtained results revealed that the ability of the cabbage fibre to bind water depended on the cultivar and the length of time the fermented cabbage was stored for (Fig. 4). Significantly greater water-binding ability was demonstrated by the fibre contained in the cabbage of the cultivars Tolerator F_1 and Agresor F_1 than by that of Tekila F_1. Rehydration capacity of dried sauerkraut increased with storage time (Fig. 4). The increase, as compared with fresh cabbage, on average amounted to 22% after 10 days from the end of fermentation; after 30 and 90 days it was at a similar level with an average value of 35%. These differences in water absorption are likely to arise from the changes in the fractional composition of the fibre, i.e. from the observed increase in the size of the cellulose fraction during sauerkraut storage. According to McConnell *et al.* (1974) and Labuza (1986), cellulose has a greater capacity for water absorbtion than do hemicelluloses and lignin.

The fibre's water-holding capacity was found to be significantly affected by the fermentation method. The WHC values of the fibre in the cabbage fermented with the addition of the starter culture were lower than those of the fibre in the traditionally fermented cabbage over the entire storage period of the fermented sauerkraut samples (Fig. 5). According to Korczak *et al.* (1995), the water-binding capacity of vegetable fibres is largely affected by the pH of the environment. The authors had demonstrated that water absorption of the fibre in apples and carrots was lower in an acid environment. Studies by Elkner and Smolińska (2002) had shown that in comparison with traditional fermentation the addition of Vege-Start culture containing strains of *L. plantarum* to facilitate better fermentation produced a rapid drop in pH and an increased amount of lactic acid, which would account for the results presented here.



Note: see Fig. 1

Fig. 3. Contents of fibre and its fractions in sauerkraut depending on kind of fermentation, year 2006

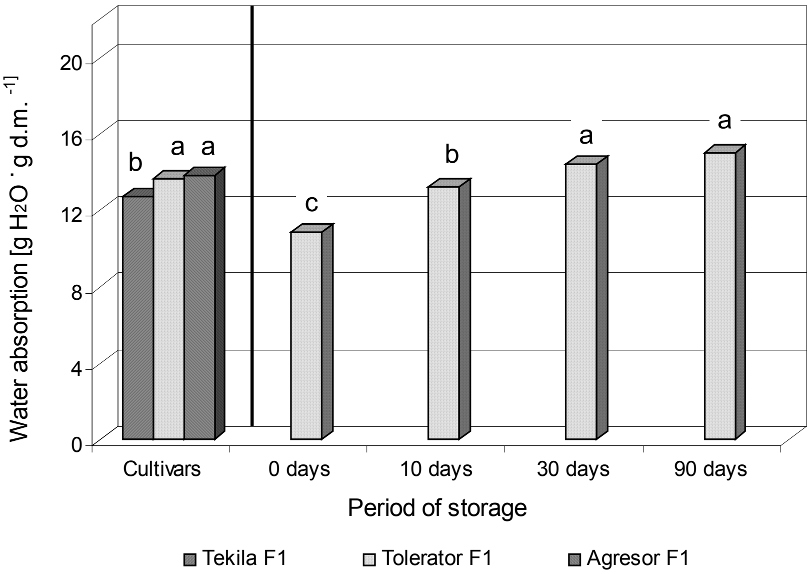


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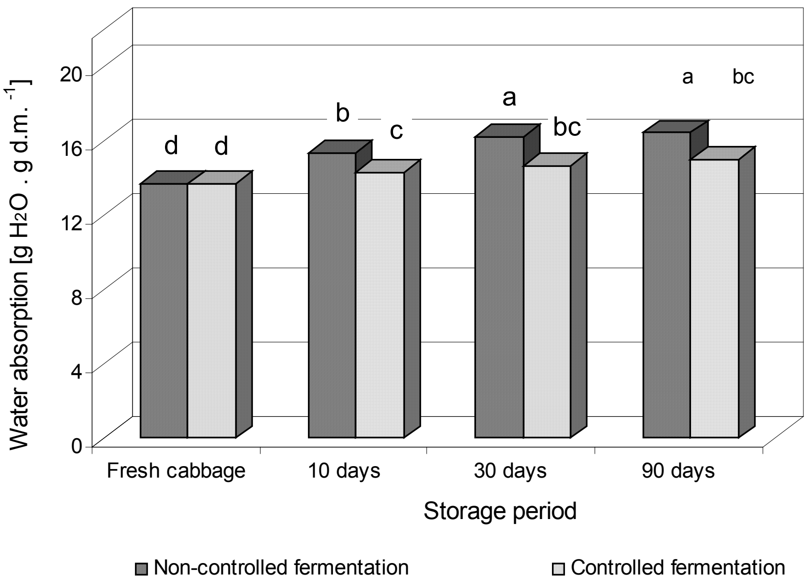
Fig. 4. Effect of cultivar and storage period on water absorption by sauerkraut fibre, averages for 3 years



Note: see Fig. 1

Fig. 5. Water absorption capacity of sauerkraut fibre depending on kind of fermentation and storage period, year 2006

CONCLUSIONS

1. Significant differences were found in dietary fibre content and its fractions among white head cabbage cultivars. The early cultivar (Tekila F_1) had a lower total fibre content and smaller cellulose and pectin fractions than the later-maturing cultivars (Tolerator F_1 and Agresor F_1).
2. The fermented cabbage (sauerkraut), as compared with the raw material, was marked by a significantly larger cellulose fraction, significantly reduced pectin fraction, slightly reduced amounts of hemicelluloses, and a similar lignin content.
3. There was no obvious effect of inoculating cabbage with starter cultures containing strains of *Lactobacillus plantarum* on the level of fibre and its fractions in the resulting sauerkraut in comparison with the traditionally fermented sauerkraut.
4. Water absorption by the cabbage fibre depended on the cultivar and on the sauerkraut storage period. The fibre of the early cultivar had a significantly lower water-holding capacity than that of the later-maturing cultivars.
5. Water-holding capacity of the fibre in the cabbage fermented with the addition of a starter culture was lower than that of the fibre in the traditionally fermented sauerkraut over the entire storage period of the fermented sauerkraut samples.

REFERENCES

Cummings J.H. 1993. Dietary fibre in Europe: an overview. In: COST 92- Dietary Fibre Intakes in Europe, (Cummings J.H. and Frolich W. ed.), Commission of European Communitres, Directorate-General, Luxembourg, 11-19.

Beecher C.W. 1994. Cancer preventive properties of varieties of *Brassica oleracea*: a review. Am. J. Clin. Nutr. 59: 1166-1170.

Eastwood M.A. 1992. The physiological effect of dietary fibre: an up date. Annual Rev. Nutr. 12: 19-35.

Elkner K., Kosson R. 1995. Skład frakcyjny błonnika pokarmowego w kapuście głowiastej białej świeżej i kiszonej. Żywność Technologia Jakość, 2(3): 48. [in Polish]

Elkner K. 2000. Effect of cultivar and nitrogen fertilization on the content of dietary fibre and its composition in some cruciferous vegetables. Veget. Crops Res. Bull. 53: 24-30.

Elkner K. 2002. The effect of thermal processing on the content of dietary fibre and its composition in some cultivars of carrots and white head cabbage. Veget. Crops Res. Bull. 56: 77-84.

Elkner K., Smolińska U. 2002. The effect of starter bacterial culture on the quality factors of sauerkraut. Veget. Crops Res. Bull. 57: 108-118.

Georing H.K., VanSoest P.J. 1970. Forage fiber analyses. Agr. Handbook, ARS/USDA, Washington, D.C. 379: 1-20.

Górecka D., Sperra L., Janitz W. 1996. [Influence of thermal processing on the functional properties under simulated conditions of digestive tract.] Rocz. AR Poznan. CCLXXXII, Technol. Żywn. 20: 35-42. [in Polish with English summary]

Hasik J., Dobrzańska A., Bartnikowska E. 1997. Rola włókna roślinnego w żywieniu człowieka. Warszawa, SGGW: 7-13. [in Polish]

King K. 1987. Method of rapid extraction of pectic substances from plant materials. Food Chem. 26: 109-110.

Korczak J., Górecka D., Janitz W., Bornikowska A., Fabrycka A. 1995. [Physico-chemical properties od dietary fiber under symulated conditions of digestive tract]. Rocz. AR w Poznaniu CCLXX, Technol. Żywn. 19: 51-59, [in Polish with English summary]

McConnell A.A., Eastwood M.A., Mitchel W.D. 1974. Physical characteristics of vegetable foodstuffs that could influence on bowel function. J. Sci. Agric. 25: 1457-1460.

Labuza T.P. 1986. Comparison of binding of fruit vegetable and cereal fibres. Cereal Food World 31, 8: 599.

Leja M., Mareczek A., Adamus A., Strzetelski M, Combik M. 2006. Some antioxidative properties of selected white cabbage DH lines. Folia Horticulturae 18/1: 31-40.

Robertson J.A., Eastwood M.A., Yemon M.M. 1980. An investigation into physical properties of fibre prepared from several carrot varieties at different stages of development. J. Sci. Food Agric. 31: 633-640.

Slavin J.L. 2001. Dietary fibre and colon cancer. In: Handbook of Dietary Fibre (Cho S.S. and Dreher M.L. ed.), Marcel Dekker, New York: 31-45.

Sorensen J.N. 1984. Dietary fiber and ascorbic acid in white cabbage as affected by fertilization. Acta Hort. 163: 221-230.

Wennberg M., Engqvist G., Nyman M. 2002. Effects of harvest time and storage on dietary fibre components in various cultivars of white cabbage (*Brassica oleracea* var. *capitata*). J. Sci Food Agric. 82: 1405-1411.

Verhoeven D.T.H., Verhagen H., Goldbohm R.A. van der Brandt P.A., van Poppel G. 1997. A review of mechanisms underlying anticarcinogenicity by *Brassica* vegetables. Chem-Biol. Interact 103: 79-129.

Verker R., Dekker M., Jongen W.M.F. 2001. Post-harvest increase of indolyl glucosinolates in response to chopping and storage of *Brassica* vegetables. J. Sci. Food Agric. 81: 953-958.

ZAWARTOŚĆ I SKŁAD FRAKCYJNY BŁONNIKA POKARMOWEGO ZALEŻNIE OD WCZESNOŚCI ODMIAN I OKRESU PRZECHOWYWANIA KAPUSTY KWASZONEJ

Streszczenie

Celem pracy było określenie zawartości błonnika pokarmowego i jego składu frakcyjnego w odmianach kapusty białej o zróżnicowanej wczesności oraz w kapuście kwaszonej w czasie jej kilkumiesięcznego przechowywania, a także określenie poziomu błonnika i jego składu w kapuście kwaszonej w zależności od sposobu kwaszenia.

Stwierdzono istotne różnice w zawartości błonnika i jego frakcji w kapuście białej w zależności od odmiany. Wczesna odmiana kapusty Tekila F_1 miała niższą zawartość błonnika ogólnego oraz frakcji celulozowej i pektynowej niż odmiany późniejsze Tolerator F_1 i Agresor F_1. Kapusta kwaszona w porównaniu z surowcem odznaczała się istotnie wyższą zawartością frakcji celulozowej, istotnie obniżoną zawartością frakcji pektynowej, niewielkim obniżeniem hemiceluloz i zbliżoną zawartością ligniny. Nie ujawnił się wyraźny wpływ szczepienia kapusty kulturami starterowymi zawierającymi szczepy *Lactobacillus plantarum* na poziom zawartości błonnika i jego frakcji w kapu-

ście kwaszonej w porównaniu z kapustą kwaszoną metodą tradycyjną. Wodochłonność błonnika kapusty zależała od odmiany, długości okresu przechowywania kapusty kwaszonej i sposobu kwaszenia. Istotnie niższą zdolność do wiązania wody wykazywał błonnik wczesnej odmiany kapusty niż odmian późniejszych. Zdolność suszu kapusty kwaszonej do rehydratacji wzrastała do 30 dni od daty kwaszenia, a dłuższe przechowywanie nie miało już wpływu na wartość wodochłonności. Wodochłonność błonnika kapusty kwaszonej z dodatkiem kultury starterowej przyjmowała mniejsze wartości w porównaniu do błonnika kapusty kwaszonej metodą tradycyjną przez cały okres przechowywania prób kwaszonych.