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The effect of alternated share of corn and oats ingredients on the fatty acids content in extrudates

Wpływ zmiennego udziału komponentów kukurydziano-owsianych na zawartość kwasów tłuszczowych w ekstrudatach

Summary. The changes in the share of fatty acids in corn and oat mixtures differing in proportion of ingredients, as affected by extrusion-cooking (temperature profile: 110/145/175/175/125°C; stock moisture: 15%), were established. Apart from the composition of the stock mixture in every extrudate a significant decline in lipids and crude fibre constituents were noted, whilst the content of nitrogen-free-extractives in dry matter increased. The share of SFA, UFA and EFA in the dry matter of extrudates was positively related to the oat bran content in the mixture prior to processing. With the low content of bran in the mixture intensive binding of UFA was observed. Once the content of oat bran was increased the binding capacity decreased significantly. At the proportion of 20% of bran the share of UFA in extrudate was as low 11% compared to the initial share in the stock mixture. With the proportion of 80% of bran, the share of UFA in dry matter reached 81% of their content in the stock mixture (prior to extrusion-cooking).

Key words: corn, oat, extrusion-cooking, fatty acids

INTRODUCTION

The world's market of extrudates is dominated by corn products [Rzedzicki 2005] whereas the other grains, including those with a high content of unsaturated fatty acids, are underestimated. It also happens with respect to oat, which should be considered as a valuable grain affecting extrusion-cooking process. Due to its chemical composition oat increases significantly the crude fat content and the share of unsaturated fatty acids as well [Lipiec *et al*. 2004]. Unfortunately, as far as today, the information on transformation of oat lipid fraction under conditions of thermoplastic processing is not clear and univocal [Bhatnagar and Hanna 1994a, Bhatnagar and Hanna 1994b, Kiczorowska 2000].

The aim of the present work was to search for the changes in fatty acid profile and to establish the concentration of fatty acids in extrudates derived from the mixtures of corn and oat stocks blended in different proportions.

MATERIAL AND METHODS

The stocks used in the study were: commercial corn grit derived from the hulled sweet corn deprived of germs and oat bran derived from the dehulled oats. The experimental factor was the alternated share of the ingredients used to formulate the mixture. The studies dealing with extrusion-cooking were carried out using twin-screw extrusion-cooker 2S-9/9 by „Metalchem" Gliwice (72 RPM, equipped with the matrix 2 × 6 mm).

In the samples the concentration of dry matter, crude protein, ether extract and crude ash was established in accordance with routine methodology treatment [AOAC 1999]. The concentration of fatty acids in the ether extract was established by gas chromatography (GC), according to the procedure described by Rotenberg and Andersen [1980], after previous saponification and esterification with 13–15% methanol solution of BF_3. The internal pattern was margarine acid. The analyses were carried out using gas chromatograph Varian CP-380 equipped with:

Column: Varian CP WAX 52CB, length 60 m, diameter 0.25 MN, temperature 210°C, the amount dosed to column: 1μl

Detector: FID, temperature 260°C

Carrier gas: helium, flow rate 1.4 ml min^{-1}

The results were given as related to the concentration of fatty acids in dry matter of the stock mixture or extrudate.

RESULTS

It should be emphasised that in the investigated range of parameters, extrusion-cooking of corn and oats mixture was appropriate. The extrusion-cooker used in the study excluded the possibility of slipping the processed mixture. The structure of the final product depended on the share of oat bran, and it was shaped like expanded snacks to gritty gruel [Rzedzicki 1999].

The slight decrease of crude protein content in dry matter of extrudates was noted, compared to the expected values, resulting from the chemical composition of stock mixture. On the other hand, a significant decrease of crude fibre (at an average of 43%) was observed as well a the remarkable increase of nitrogen-free-extract (at an average of 2.8%), related to the stock mixture.

The decline of ether extract content in dry matter of extrudates was noted as well. With respect to 20% share of oat bran, the concentration of fat was as low as 12.5% compared to its content in the mixture prior the extrusion-cooking. It was clear that the share of oat bran adversely affected binding of the fat. With 80% of bran, the concentration of fat in the extrudate reached the level above 90% of its content in the untreated stock. The very high value of determination coefficient (R^2 = 0.986) reveals that the experimental results were not accidental, but they were very systematic and depended on the share of oat bran in the mixture.

Table 1. Extrusion-cooking parameters
Tabela 1. Parametry procesu ekstruzji

Variant Wariant	Proportion (%) Udział surowca (%)		Stock mixture humidity (%) Wilgotność mieszanki (%)	Temperature profile of cylinder (°C) Profil rozłożenia temperatury w cylindrze (°C)
	corn grit kaszka kukurydziana	oat bran otręby owsiane		
A	80	20	15	110/145/175/175/125
B	70	30		
C	60	40		
D	50	50		
E	40	60		
F	30	70		
G	20	80		

Table 2. The basic chemical composition of stock mixtures and extrudates (% of DM)
Tabela 2. Podstawowy skład chemiczny surowców i ekstrudatów (% sm)

Variant Wariant		Dry matter Sucha masa	Crude ash Popiół surowy	Crude protein Białko ogólne	Ether extract Tłuszcz surowy	Crude fibre Włókno surowe	NFE BAW
A	S	90.19	1.84	11.52	2.57	0.88	83.19
	E	92.07	1.93	11.85	0.32	0.45	85.45
B	S	90.37	2.08	12.24	3.09	0.98	81.61
	E	92.39	2.04	12.05	0.85	0.53	84.54
C	S	90.55	2.28	12.96	3.61	1.08	80.07
	E	92.13	2.23	12.86	1.61	0.60	82.71
D	S	90.72	2.37	13.67	4.13	1.18	78.65
	E	92.21	2.36	13.21	2.18	0.61	81.65
E	S	90.90	2.70	14.39	4.65	1.28	76.98
	E	92.03	2.66	13.93	3.40	0.77	79.25
F	S	91.08	2.79	15.11	5.17	1.38	75.55
	E	92.50	2.81	14.43	4.34	0.80	77.61
G	S	91.26	2.98	15.82	5.69	1.48	74.03
	E	92.29	3.02	15.24	5.13	0.97	75.65

S – stock mixture, mieszanina surowa
E – extrudate, ekstrudat

The data covering the effect of extrusion-cooking on the content of fatty acids in the dry matter of extrudates are also very interesting. The direction of changes of both saturated and unsaturated fatty acids was similar to the changes of the crude fat concentration (Fig. 1). In the extrudates containing higher proportions of oat bran, an increased share of SFA and UFA in the dry matter was noted. These values almost reached the levels established in the stock mixture, prior to processing.

Table 3. The share of fatty acids in dry matter of stock mixtures and extrudates (mg·g^{-1} DM)
Tabela 3. Zawartość kwasów tłuszczowych w suchej masie surowców i ekstrudatów (mg·g^{-1} sm)

Variant Wariant		C 14:0	C16:0	C16:1	C18:0	C18:1	C18:2	C18:3	C 20:n
A	S	0.05	4.28	0.06	0.75	9.96	7.41	0.33	0.26
	E	0.01	0.84	0.01	0.12	1.49	0.38	0.02	0.02
B	S	0.06	5.36	0.06	0.86	12.36	8.35	0.37	0.34
	E	0.04	2.61	0.02	0.30	3.93	0.38	0.12	0.19
C	S	0.07	6.52	0.07	0.97	14.90	9.10	0.41	0.43
	E	0.15	4.85	0.02	0.55	7.17	0.39	0.30	0.71
D	S	0.08	7.74	0.07	1.07	17.57	9.66	0.43	0.52
	E	0.14	5.95	0.16	0.59	9.94	1.54	0.33	0.74
E	S	0.10	9.04	0.08	1.15	20.36	10.03	0.44	0.63
	E	0.15	9.80	0.00	0.78	16.09	2.21	0.25	1.04
F	S	0.11	10.41	0.08	1.23	23.30	10.22	0.45	0.74
	E	0.16	10.07	0.00	0.69	17.23	9.19	0.30	0.76
G	S	0.13	11.85	0.08	1.29	26.36	10.21	0.45	0.86
	E	0.19	10.76	0.00	0.95	19.90	9.78	0.40	0.78

S – stock mixture, mieszanina surowa
E – extrudate, ekstrudat

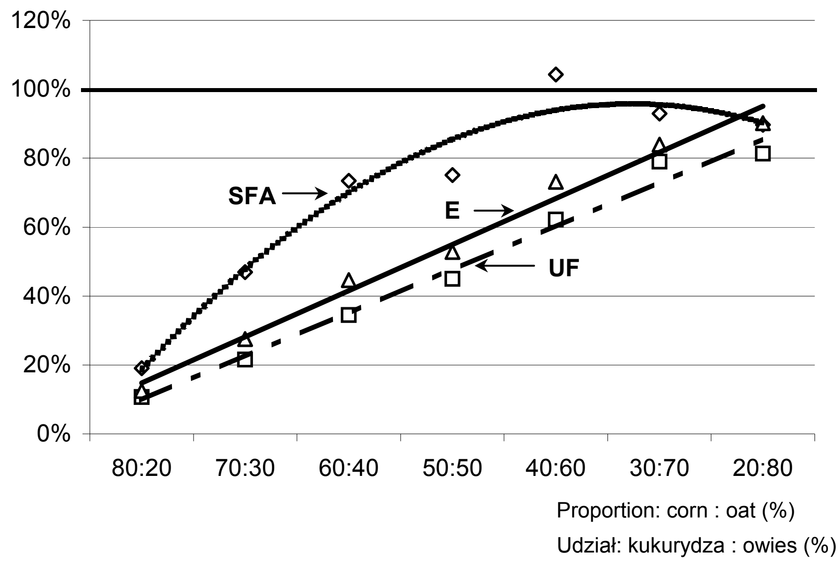

Fig. 1. Changes in the share of EE, SFA and UFA in extrudates related to their proportion in the unprocessed mixture
Rys. 1. Zmiany udziału tłuszczu surowego (EE), nasyconych (SFA) i nienasyconych (UFA) kwasów tłuszczowych w ekstrudatach w stosunku do ich zawartości w mieszaninie surowej

EE = 0.134x + 0.014; R^2 = 0.986
SFA = $0.035x^2 + 0.396x - 0.175$; R^2 = 0.956
UFA = 0.127x – 0.029; R^2 = 0.985

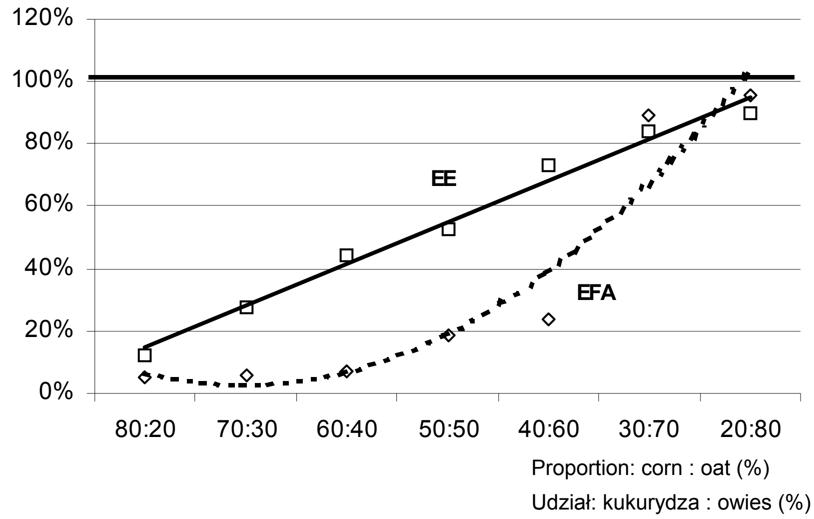

Fig. 2. Changes in the share of EE and EFA in extrudates related to their proportion in the unprocessed mixture
Rys. 2. Zmiany udziału tłuszczu surowego (EE) i niezbędnych nienasyconych kwasów tłuszczowych (EFA) w ekstrudatach w stosunku do ich zawartości w mieszaninie surowej

EE = 0.134x + 0.014; $R^2 = 0.986$
EFA = $0.0401x^2 – 0.159x + 0.183$; $R^2 = 0.917$

Significant changes were noted with respect to the concentration of UFA in dry matter of extrudates. In the extrudates with a high share of corn, UFA were intensively complexed whilst a higher proportion of oat bran decreased their binding. With the 80 % share of oat bran the content of unsaturated fatty acids increased up to 81% of the level established in the stock mixture. The observed relation of changes was confirmed by the value of determination coefficient ($R^2 = 0.985$).

A similar relation was noted with essential fatty acids (EFA) (Fig. 2). The lowest concentration of EFA (5.2–7.3%) was found in extrudates containing 20 through 40% of oat bran, related to the expected values resulting from the stock formula. In the samples containing 70–80% of oat bran the EFA level increased up to 89–96%, compared to their concentration in the stocks, prior extrusion-cooking.

DISCUSSION

The loses of nitrogen observed during extrusion-cooking resulted from the formation the isopeptide bindings between amide groups of asparagine and/or glutamine and ε-groups of lysine. These reactions are followed by emission of ammonia which occurs during expanding of product [Stanley 1989]. Similar relations were also revealed by Zieliński and Rzedzicki [2001].

The increment of oat bran share in the stock mixture results not only in the increase of ether extract but it also increases the content of soluble fraction of dietary fibre, including (1–3) (1–4) β-D glucans, whose concentration in oat is very high, compared to the other cereals. The combined effect of both fat and mucous fraction of soluble dietary fibre was believed to prevent the reactions between lipids and proteins and lipids and starch as well [Kahlon *et al.* 1998].

The presented data reveal that the saturated fatty acids are the least tractable to lipid-protein and lipid-starch interactions, nevertheless the most reactive was the stearic acid. Over and above it should be stated that the share of SFA was rather low, compared to the remaining acids in the examined mixture of corn and oat; therefore, the fraction of the fat bound up with extrudates consisted predominantly of lipids containing unsaturated fatty acids.

With respect to unsaturated fatty acids some interactions of C18:1 were observed resulting from the increased level of oat bran. The mentioned relations were especially noticed with the share of C18:2 and C18:3 fatty acids (Tab. 3).

The results of the experiment force us to revise the opinion on thermal processing of oat products. These products undergo thermal processing to inactivate lipase and to protect the lipids against autooxidation, which is necessary to extend the expiry term. On the other hand, the conditions of thermoplastic processing should be considered in terms of possible binding of lipids and individual fatty acids as well. It should be also noticed that there are no unbiased results of research dealing with the digestion of lipid-starch and lipid-protein complexes in humans, which seems especially important with respect to polyunsaturated fatty acids, including linoleic and linolenic acids, easily forming complexes with proteins and polysaccharides.

A new approach to extrusion-cooking of oat products results from the experiments by Lehtinen *et. al.* [2003] revealing that intensive heat treatment increases oxidation processes due to the destruction of temperature sensitive antioxidants. Resulting from the present research it should be emphasised that extrusion-cooking has an advantage compared to non-pressure heat treatments since this method not only leads to binding lipids but also to absorbing them by starch and protein mass which protects fat from oxidation.

CONCLUSIONS

1. Extrusion-cooking of the mixture with an alternated share of corn grit and oat bran in the twin-screw extruder allows to obtain products differing in the structure and chemical composition.

2. Binding lipids in the corn and oat extrudates decreases proportionally to the increment of oat bran in the stock mixture.

3. Unsaturated fatty acids, especially oleic acid, are especially sensitive to binding by extrudates.

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Streszczenie. W mieszankach kukurydziano-owsianych o zmiennym udziale komponentów badano zmiany zawartości kwasów tłuszczowych pod wpływem procesu ekstruzji prowadzonego w stałych warunkach technologicznych (profil temperatury cylindra: 110/145/175/175/125 ^{o}C; wilgotność mieszaniny: 15%). Niezależnie od składu mieszaniny surowcowej we wszystkich ekstrudatach stwierdzono wyraźne obniżenie zawartości tłuszczu wolnego, składników włókna surowego oraz wzrost zawartości związków bezazotowych wyciągowych w suchej masie. Wraz ze wzrostem udziału otrąb owsianych obserwowano rosnący udział SFA, UFA i EFA w suchej masie ekstrudatów. Przy niskim udziale otrąb owsianych następowało intensywne wiązanie UFA, które obniżało się bardzo szybko w miarę wzrostu udziału otrąb. Przy 20-procentowym udziale otrąb oznaczono zaledwie 11% zawartości UFA w porównaniu z ich koncentracją w mieszance surowcowej. Natomiast przy udziale 80% otrąb zawartość UFA w suchej masie zwiększyła się do 81% ich zawartości oznaczonej w mieszance surowcowej.

Słowa kluczowe: kukurydza, owies, ekstruzja, kwasy tłuszczowe