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EFFECT OF EXTRUSION CONDITIONS ON PHYSICAL PROPERTIES OF BUCKWHEAT–MAIZE BLEND EXTRUDATE

Adam Ekielski, Zbigniew Majewski, Tomasz Żelaziński

Department of Production Management and Engineering, Faculty of Production Engineering, Warsaw University of Life Sciences, Warsaw

Key words: extruder, buckwheat, physicochemical properties

The effect of extrusion conditions on the physicochemical properties, such as: volumetric expansion (VEI), water absorption index (WAI), water solubility index (WSI), density, mechanical strength of buckwheat-maize extrudate was investigated. The following levels of variables were used: moisture content 12.15%, buckwheat content 15, 30, 45, 60 and 100%, barrel temperature (last section) 120°C.

An increase in feed moisture content resulted in extrudate's higher density, lower expansion, higher WAI, and lower WSI. The higher buckwheat content increased extrudate's expansion, WSI and WAI, while decreased its mechanical strength.

INTRODUCTION

In recent years one can observe wide interests in healthy food, namely dietetic, gluten-free, high-cellulose products or those fortified with new "natural" additives of high biological value (like buckwheat or its mixtures).

Buckwheat has been known and cultivated since 4000 years, and it can be found in Japan, USA, China, Poland, South Africa or Brasil. The present world's harvest of buckwheat amounts to about 3.3 million tons, compared to 2 million tons in 1999 [Kostecki, 2005]. This increase results from particular properties of buckwheat, which contains proteins of advantageous amino acid composition and is characterised by biological value higher than milk protein or pork meat [Steadman *et al*., 2001]. Buckwheat grain contains a series of microelements: potassium, magnesium, iron, chromium, zinc, cobalt as well as B and E group vitamins. It is also gluten-free and is recommended for people suffering from diabetes or celiac disease [Kraskowa & Mrazova, 2004].

However, the increased popularity of buckwheat products would call for their wider diversity. One of possible solutions is extrusion of buckwheat [Edwardson, 1996], which can yield new ready-to-eat products, like extruded crisps or groats-like products and many others.

So far only limited number of investigations have been carried out on buckwheat mixtures. Rayas-Duarte *et al*. [1998] investigated the extruded products obtained from flour of maize, wheat and buckwheat in a double-screw extruder, where addition of buckwheat amounted to 30, 40, 55%. Cichon *et al*. [1993] investigated the effect of extrusion conditions in a single-screw extruder on the nutritional value of maize and buckwheat grit with addition of casein. It was found that 20% addition of buckwheat improved the extrudate's nutritional value.

The undertaken investigations aimed at determining the effect of buckwheat addition on technological and physical properties of extruded buckwheat-maize mixtures.

MATERIAL AND METHODS

The mixture consisting of maize ground grain and variable buckwheat grit content: 0, 15, 30, 45, 60 and 100% was extruded at two moisture contents, *i.e.* 12% and 15%. There was used a single-screw extruder KZM-2 of the following parameters: screw speed n=200 rpm, screw length to diameter ratio L/D=6.5 and die outlet hole diameter 12 mm. The extruder was equipped with resistance heaters of 3000 W, enabling to maintain a constant process temperature equal to about 120°C.

The volumetric expansion ratio was determined with Alvarez-Martinez method [1988], and Ekielski & Osiak [2003], while water solubility index (WSI) and water absorption index were determined with Anderson method [1969]. The method included careful mixing of comminuted extrudate (mass of 2.5 g and particle size of 180-250 μm) with 25 mL of distilled water. The excess of water was separated in a centrifuge at 3000 rpm for 10 min, then the sample was weighed and dried at 105°C.

The investigated indices were calculated as follows:

WAI =weight of sediment/weight of dry solids

WSI(%) = weight of dissolved solids/weight of dry solids

Author's address for correspondence: Adam Ekielski, Department of Production Management and Engineering, Faculty of Production Engineering, Warsaw University of Life Sciences, ul. Nowoursynowska 164, 02-787 Warsaw, Poland; tel./fax; (48 22) 5934561; e-mail: adam_ekielski@sggw.pl

TABLE 1. Results of ANOVA test for the effect of buckwheat addition on quality indices.

Effect	One-way analysis of variance Sigma-limitation parameters Effective hypothesis decomposition				
	SS	Degree of freedom	MS	F	p
Expansion					
Free term	1696.421	1	1696.421	5758.829	0.000000
Buckwheat content (%)	15.085	5	3.017	10.241	0.000001
Moisture content (%)*	0.000	1	0.000	0.000	1.000000
WAI					
Free term	411.3156	1	411.3156	5016.603	0.000000
Buckwheat content (%)	4.9865	5	0.9973	12.163	0.000002
Moisture content (%)	0.9894	1	0.9894	12.067	0.001633
WSI					
Free term	12899.31	1	12899.31	1461.801	0.000000
Buckwheat content (%)	243.23	5	48.65	5.513	0.001097
Moisture content (%)	751.56	1	751.56	85.169	0.000000
Mechanical strength					
Free term	0.184092	1	0.184092	2595.840	0.000000
Buckwheat content (%)	0.010021	5	0.002004	28.261	0.000000
Moisture content (%)*	0.000010	1	0.000010	0.144	0.705968

* values of a statistical index are not significant at $p<0.05$

The mechanical strength of extrudate was measured with the use of Instron 4301 equipped with a knife head. The results of particular tests were recorded in a computer with the use of Lab.Instron software.

The colour parameters: L* (brightness), a*(red/green colour parameter), b* (yellow/blue colour parameter) were determined according to the methodology of Kit [2004]. The measurements were executed on a research stand consisting of a light chamber equipped with daylight fluorescent lamps of colour temperature 6500 K and photo camera Nikon 8700, where a white balance was made on the white pattern of Minolta make. The obtained samples were photographed and the shots were recorded in TIF format. Ten fragments of several elements and marked with a circle of 10 mm diameter were randomly chosen for colour analysis, neglecting the empty spaces. The colour analysis was performed with the use of Adobe Photoshop 6.0. CE, where the values of parameters L*, a*, b* were obtained with the histogram function.

The obtained results were analysed statistically with the use of ANOVA module for main effects in Statistica 6.0 software.

RESULTS AND DISCUSSION

The effect of buckwheat addition on quality indices of buckwheat-maize extrudate was determined. The mean values of quality indices were taken as an estimator: expansion, WAI, WSI, mechanical strength and colour coefficients L^*, a^*, b^*, at a significance level of $p<0.05$. The following hypotheses were advanced: H_0 – buckwheat addition does not influence the above-mentioned quality indices: expansion, WAI, WSI, mechanical strength; H_1 – moisture content of raw material does not influence the above-mentioned quality indices: expansion, WAI, WSI, mechanical strength; H_2 – buckwheat addition and moisture content do not influence the colour indices L^*, a^*, b^*.

Expansion

Basing on the results obtained (Table 1), the hypothesis H_0 on the lack of the effect of buckwheat content on volumetric expansion ratio can be rejected, therefore, there is a statistically significant dependence between these factors. An increase in moisture content up to 15% was found not to influence the expansion ratio (Figure 1). However, at both moisture contents: 12% and 15%, when buckwheat content was increased, the expansion ratio increased considerably. The highest value of this coefficient was at moisture content of 12% and buckwheat content of 100%.

Texture – mechanical strength

The results of Anova test enable also rejecting the hypothesis H_0 on the lack of the effect of buckwheat content on mechanical strength index. However, the hypothesis H_1 cannot be rejected; this means that an increase in moisture content from 12% to 15% does not affect the investigated index. It was found that an increase in buckwheat content (Figure 2) caused a decrease in the mechanical strength, and the biggest difference 100% buckwheat content and 100% maize content amounted to 0.046 J/mm^2 at 12% moisture content.

Water solubility index (WSI) and water absorption index (WAI)

Considering values of water solubility index (WSI) and water absorption index (WAI) one can find that hypotheses H_0 and H_1 on the lack of the effect of buckwheat content on

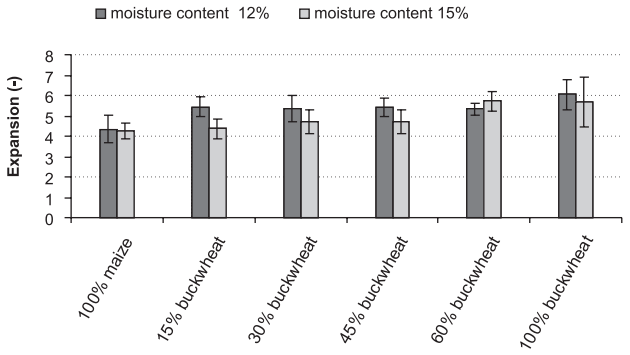

FIGURE 1. Effect of moisture content on expansion ratio of maize-buckwheat extrudate.

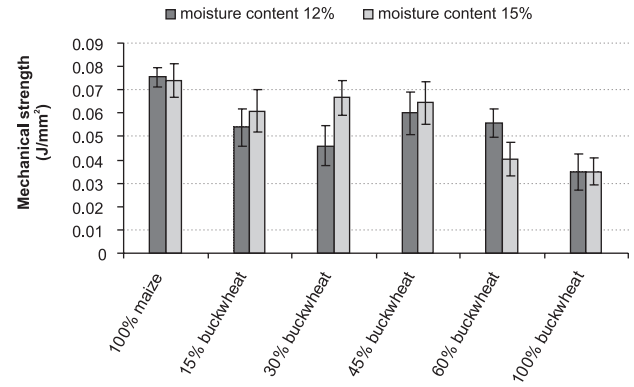

FIGURE 2. Effect of moisture content on mechanical strength of maize--buckwheat extrudate.

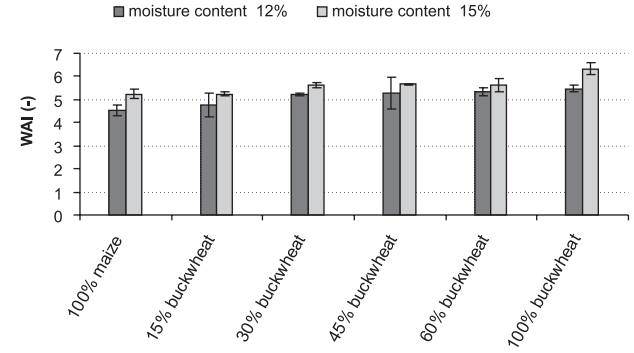

FIGURE 3. Effect of moisture content on water absorption index (WAI) of maize-buckwheat extrudate.

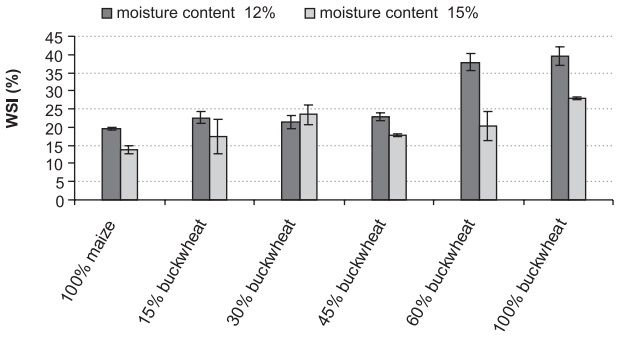

FIGURE 4. Effect of moisture content on water solubility index (WSI) of maize-buckwheat extrudate.

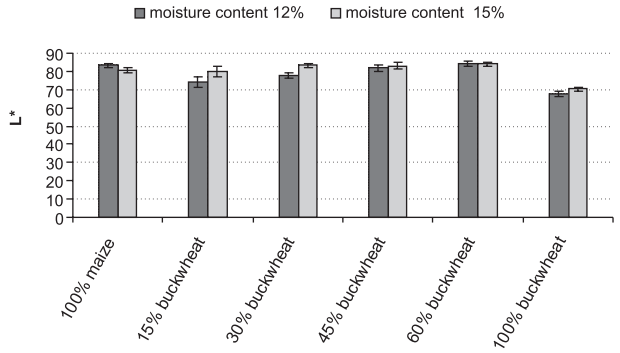

FIGURE 5. Effect of moisture content on colour coefficient L* of maize--buckwheat extrudate.

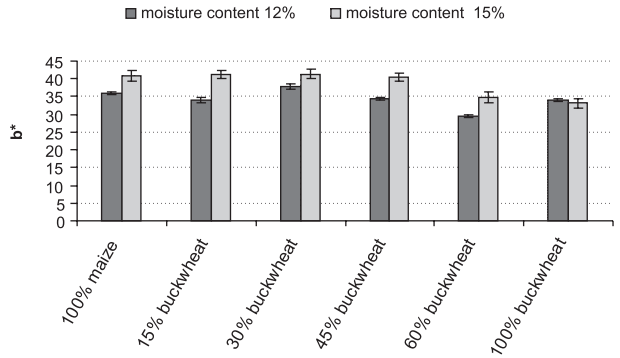

FIGURE 6. Effect of moisture content on colour coefficient b* of maize--buckwheat extrudate.

WSI and WAI coefficients can be rejected. The WSI values (Figure 3) increase with buckwheat content at both moisture contents, particularly at buckwheat contents of 60% and 100% at moisture content of 12% (the highest values amounted to 37.9% and 39.6%, respectively).

The WAI coefficient values increased also with an increase in buckwheat content, and at moisture content of 15% they were higher than at 12% (Figure 4).

Colour

Table 2 presents results of colour investigations for brightness coefficient L*. The hypothesis H_2 on the lack of the effect of buckwheat content on L^* parameter value can be rejected. A linear tendency in this parameter's values can be observed up to 60% of buckwheat content (Figure 5), then the values decrease considerably (the product's brightness decreases).

Considering the results of analysis for colour coefficient a* it was found that hypothesis H_2 could not be rejected. Therefore, both the buckwheat content and moisture content did not influence significantly the changes in the investigated coefficient.

In analysis of colour coefficient b* the hypothesis H_2 was rejected. At both moisture contents the values of coefficient b^* decreased with an increase in buckwheat content (Figure 6).

TABLE 2. Results of ANOVA test for the effect of buckwheat addition on colour attributes.

Effect	One-way analysis of variance Sigma-limitation parameters Effective hypothesis decomposition				
	SS	Degree of freedom	MS	F	p
		L*			
Free term	768660.5	1	768660.5	86058.05	0.000000
Buckwheat content (%)	397.1	1	397.1	44.46	0.000000
Moisture content (%)	1418.3	5	283.7	31.76	0.000000
		a*			
Free term	6578.445	1	6578.445	308.6651	0.000000
Buckwheat content (%)*	60.941	1	60.941	2.8594	0.093599
Moisture content (%) *	180.960	5	36.192	1.6982	0.140742
		b*			
Free term	159742.2	1	159742.2	39466.07	0.000000
Buckwheat content (%)	581.7	1	581.7	143.71	0.000000
Moisture content (%)*	850.2	5	170.0	42.01	0.000000

* values of a statistical index are not significant at $p<0.05$

SUMMARY AND CONCLUSIONS

Basing on the carried out investigations there were analysed dependences between quality indices and buckwheat content in the maize-buckwheat mixture. It was found that various buckwheat contents and moisture contents influenced significantly the quality indices of extrudate, including colour coefficients L*, a*, b* determining the quality of the products. Therefore in further investigations one should search for dependences between particular physical properties of extrudate in order to properly model the quality of mixtures processed during extrusion.

It was found that buckwheat content in the mixture differentiated all the investigated indices. An increase in percent content of buckwheat caused sometimes a rapid increase (expansion, WSI, WAI), or a decrease in the investigated indices (mechanical strength, colour coefficients L*, b*). It was found that changes in buckwheat content did not influence the colour coefficient a*, while moisture content affected all indices with exception for expansion ratio, mechanical strength and colour coefficient a*.

An increase in moisture content to 15% caused a decrease in water solubility index (WSI). At the same moisture content the WAI values were higher (higher water absorption).

In the mixtures containing up to 60% of buckwheat the product's brightness did not change, however, above this value L* value decreased rapidly, probably due to characteristic properties of buckwheat or a longer residence time of mixture in the extruder. The colour parameter b* increased with buckwheat content, while parameter a* was not influenced by buckwheat content nor by the moisture content.

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WPŁYW WARUNKÓW PROCESU EKSTRUZJI NA WŁAŚCIWOŚCI FIZYCZNE EKSTRUDATU GRYCZANO-KUKURYDZIANEGO

Adam Ekielski, Zbigniew Majewski, Tomasz Żelaziński

Zakład Organizacji i Zarządzania Produkcją, Wydział Inżynierii Produkcji, Szkoła Główna Gospodarstwa Wiejskiego, Warszawa

W badaniach przedstawiono wpływ warunków procesu ekstruzji na właściwości fizyczne otrzymywanego ekstrudatu gryczano-kukurydzianego. Wskaźnikami, które oznaczano były: współczynnik ekspansji (VEI), współczynnik wodochłonności (WAI), rozpuszczalność (WSI), gęstość, wytrzymałość mechaniczna i barwa. Przygotowane mieszanki zawierały następującą zawartość gryki w stosunku do kukurydzy: 15, 30, 45, 60 i 100%. Wilgotność materiału wykorzystywanego do ekstruzji wynosiła 12 i 15%. Ekstruzję przeprowadzano w temperaturze 120°C.

Wraz ze wzrostem wilgotności zanotowano wyższą gęstość ekstrudatu, niższą wartość współczynnika ekspansji, większą wodochłonność i niższą wartość współczynnika rozpuszczalności. Czym większa była zawartość gryki tym wartość współczynnika ekspansji była wyższa, wzrastała również wartość WAI i WSI, natomiast zanotowano mniejszą wytrzymałość mechaniczną.