THE EFFECT OF SPELT ADDITION ON THE PROPERTIES OF EXTRUDED PRODUCTS WITH ENHANCED NUTRITIONAL PROPERTIES
/
WPŁYW DODATKU ORKISZU NA WŁASNOŚCI EKSTRUDOWANYCH WYROBÓW O PODWYŻSZONYCH WŁASNOŚCIACH ŻYWIENIOWYCH

Ph.D.Eng. Żelaziński T.*[1)], Ph.D. DSc. Eng. Ekielski A.[1)], MSc.Eng Siwek A.[2)], Ph.D. Eng. Stachelska M.[2)], Ph.D. Stud. Eng. Florczak I.[1)]

[1)]Department of Production Management and Engineering. Warsaw University of Life Sciences– SGGW / Poland;
[2)]Food Technology and Gastronomy Institute, Lomza State University of Applied Sciences / Poland
Tel: +48225934565; E-mail: tomasz_zelazinski@sggw.pl

Keywords: *extrusion, spelt, quality investigation*

ABSTRACT

The aim of the study was to produce extruded material with the highest possible content of spelt and to examine the qualitative properties of the products obtained. Tests were carried out on a synchronous twin-screw extruder with L:D ratio 27, at different temperatures, screw speed, material feeding and raw material moisture. To determine the quality properties there were used parameters such as density, expansion, WSI and WAI, water activity and porosity. The results were promising, all the products were characterized by a high degree of water-holding capacity, and their quality was similar to conventional corn extrudates.

STRESZCZENIE

Celem pracy było wytworzenie surowców ekstrudowanych z możliwie wysokim udziałem orkiszu i zbadanie właściwości jakościowych uzyskanych produktów. Badania przeprowadzono na ekstruderze dwuślimakowym, współbieżnym o stosunku L:D 27, przy różnych ustawieniach temperatury, prędkości obrotowej ślimaków, podawania surowca oraz wilgotności materiału. Do określenia parametrów jakościowych wykorzystano takie parametry jak: gęstość, ekspansję , WSI i WAI, aktywność wody oraz porowatość. Uzyskane wyniki były obiecujące, wszystkie produkty charakteryzowały się wysokim stopniem wodochłonności, a ich jakość była zbliżona do klasycznych ekstrudatów kukurydzianych.

INTRODUCTION

Extrusion is a universal process of raw materials treatment, which enables the production of new and innovative products. It is allowed not only by the specifics of the process itself but also by the possibility of raw materials processing, where traditional processing methods are not cost-effective or economically reasonable *(Żelaziński et al, 2014a)*. Such materials include spelt wheat with numerous positive properties that support its broad application. However, such products range is now very limited.

In Polish and world's literature spelt is described quite widely. The studies include not only the quality characteristics of the finished products but also the physicochemical parameters of grains themselves Sacchetti et al. 2004. Therefore, over the past few years there could be found a number of studies showing different quality characteristics for spelt products or their blends with other cereals. The most popular products include spelt bread and other baked products (e. g. muffins, pastries), widely reported in the research literature *(Abdel et al, 2008; Ruibal-Mendieta et al. 2002; Pierogiovanni et al, 1996; Skrabanja et al, 2001; Escarnot et al, 2010)*. Research areas also include analysis of the spelt baking flour, for example the study conducted by Radomski et al., (2007).

There were also some attempts made to use spelt flour in pasta production *(Marconi et al, 1999, 2002)*. These results suggest that the quality of spaghetti pasta is the highest with the maximum spelt share and relate it with a high content of high-quality protein in the flour. In the literature, there are also other spelt products compared. For example, quality analysis of the bread, pasta and crunchy extruded products manufactured on the basis of spelt flour were conducted by Bonafaccia et al, (2000). In this case, there were found large differences in the degree of starch gelatinization and easily digestible protein content.

The literature however still contains a few studies on the extrusion of spelt or its mixes, and presented research include products based on typical varieties of wheat *(Kim et al, 2006; Yuan et al, 2013)*. It also addresses the topics such as the physical properties of grains, where the aim usually is to improve existing solutions or to find new ways of threshing and hulling spelt *(Borkowska and Robaszewska, 2013; Frączek and Reguła, 2010; Choszcz et al. 2010)*. Difficulties in obtaining clean grains in combination with a smaller wheat yield are also one of the main reasons affecting the small spelt production.

Summing up the above, spelt is certainly a perspective raw material, and researches of its different products carried out in recent years demonstrate the need to search for its new applications, e. g. with the use of extrusion process.

MATERIAL AND METHOD

Material and extrusion process

Input material designed for extrusion was whole-meal spelt flour (total fat 2.7%, total protein approx. 12%) and corn meal (total fat 0.7%, total protein approx. 8.3%, starch approx. 75%). From those materials there were prepared 4 blends in which the share of spelt flour was 70%, 80%, 90% and 100% of total volume. Raw material moisture amounted to approx. 13.6%.

Investigations were conducted in a laboratory twin-screw extruder Clextral Evolum 25 with length to screw diameter ratio L:D of 27. The extruders' cylinder was equipped with six heaters and cooling water system. Such number of sections in conjunction with the two-state automation system allowed very precise adjustment and control of the temperature profile during the extrusion process.

As extruder die was used a circular one with a diameter of 2.5 mm. At the head of the extruder there was placed a cutter, with speed control possibility at the range of 0-1400 obr·min^{-1} (cutter speed was 400 obr·min^{-1}). The extruder was equipped with a calibrated volumetric feeder and a water pump to enable a precise dispensing of liquid directly into the extruder barrel of 0.001 dm^{3}·min^{-1} accuracy.

During the extrusion process, temperature and the screw rotation speed was being changed. Temperature profile set in the individual sections of the extruder barrel was 120°C, 120°C, 110°C, 80°C, 30°C, 30°C and 140°C, 140°C, 110°C, 80°C, 30°C, 30°C. During the extrusion process there was also changed the screw speed in the range 300 or 350 obr·min^{-1}.

The resulting extrudates were prior to being cooled at room temperature for a period of about 3 hours until the moisture stability of approx. 11% was obtained. Below, there is a set points plan for the process of extrusion which was used for all extruded blends.

Table 1

Parameters of extrusion

Extrusion set points	Temperature	Rotation
I	120	300
II	140	300
III	120	350
IV	140	350

Quality properties analysis

Physico-chemical properties of obtained samples were determined by using the basic quality parameters such as density, radial expansion, water absorption (WAI) and water solubility (WSI) indices, water activity and structure measured in the cross-section of the extrudate.

Density was studied with displacement method carried out in accordance with the standard (BN-87/9135-05). Radial expansion (sectional expansion) was determined according to the method (Alvarez-Martinez et al. 1988) as the ratio of the extrudate diameter to the diameter of the nozzle array. Tests of WAI and WSI indices were conducted by the method of Anderson et al. (1969), and shown in detail in the work of Ekielski et al. (2007).

Strength tests of extrudates (texture characteristics) were carried out on the testing machine AXIS 500 (Poland) equipped with a head for measuring the strength (max 25 N). Maximum force needed to cut the extrudate was examined. At the head it was placed a circular mandrel with a diameter of 2 mm (feed rate of 0.02 mm·s^{-1}, displacement of 11 mm). The samples used in the tests had a diameter between 5 and 7 mm and a length between 5.2 and 7.1 mm.

Porosity was studied on a test image analysis stand equipped with a microscope and image analysis software: stereo microscope Opta Tech SL + 3 Mpixel camera. Pictures were recorded in TIF format in the resolution of 2048 x 1536. The porosity was determined according to the method of Gosselin&Rodrigue (2005), using irregular boundaries of the analyzed group of air pores on the evaluated images.

For the porosity analysis it was used package with LabView 2013 and the Vision Assistant 7.1.1 program, where the photos were graphically designed. Then, the obtained images with byte gray scale (256 levels) were converted into divalent bitmaps and were chosen the appropriate thresholds of gray scale range from 1-255 *(Żelaziński et al, 2014b; Ekielski A., 2011)*. In this way, the porosity of the samples was determined on the cross-sectional areas as the number of pores per unit area (cm^2) in accordance with Hayter et al. (1989).

For measuring the water activity of the products obtained there was used AquaLab 4TE measurer (Dekagon, USA). For research results description the Statistical 12 analytical program was used.

RESULTS

On the basis of the analysis of obtained results, it was found that changes in various parameters of the extrusion process had a significant impact on the qualitative changes of the samples obtained. It was found that the density of extrudate (Fig. 1) decreases with the increase of the spelt flour content in the mixture, which could be observed in all samples tested.

At settings of extrusion process I, III, IV charts' courses were similar and the highest density of approx. 0.13 g$\cdot$cm^{-3} was observed with the spelt participation in a blend of 70%. At settings extrusion process II, all the extrudates have a higher density, the maximum average value being of 0.175 g$\cdot$cm^{-3} for a mixture of 70% spelt.

The graph course showing the change of radial expansion coefficient looks conversely (Fig. 2). It can be seen that with the increase of the spelt flour content index values clearly increase. In this case, the maximum values of the expansion index were achieved for blends involving 100% of spelt flour. Between the density and the expansion coefficient for process settings I, II, III, IV, it were also found negative correlations at -0.825, -0.648, -0.887, -0.641. Lower density and simultaneously larger degree of the radial expansion suggests that whole-meal spelt flour can be a good structure-forming raw material.

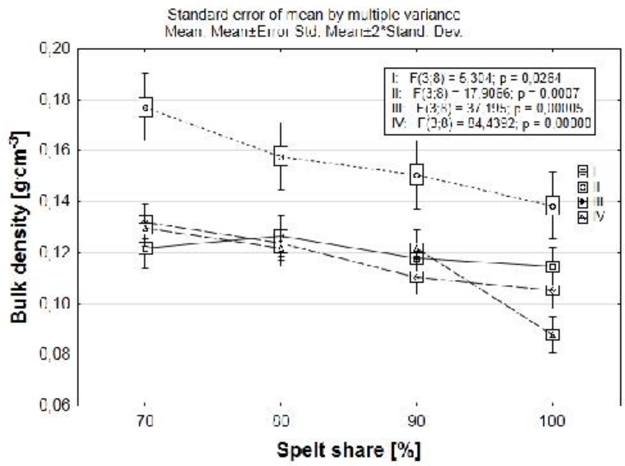

Fig. 1 - Influence of spelt content on density changes of extrudates

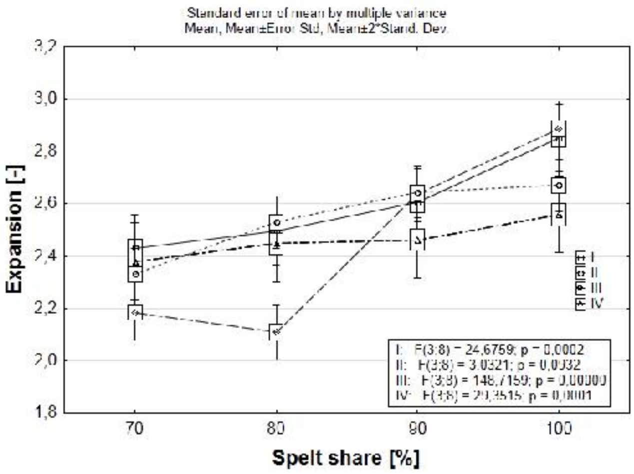

Fig. 2 - Influence of spelt content on expansion changes of extrudates

It was found that with increasing spelt content in the mixture water absorption WAI is also reduced (Fig. 3). In the case of setting I, III and IV, this parameter in the raw material consisting of 100% spelt was 3.45 to 3.5, while for the samples with 70% of spelt was 3.92 to 4.04 on average. The greatest water absorption was characterized by the samples obtained with setting III.

Proportionally and conversely there is presented the course of the WSI index chart (Fig. 4). On the graph it can be thus observed an increase in WSI with the increase of spelt content in the mix, where the maximum water solubility was achieved with 100% spelt participation. In this case, the parameters of the WAI and WSI are also strongly correlated, what is stated in all settings of the process I, II, III, IV (-0.845, -0.774, -0.623, -0.927). Water-holding capacity parameter was also strongly correlated with Aw, what was found with the extruder setting I, II and IV (-0.826, -0.853, -0.954).

Overall, according to the literature (*Ekielski et al, 2007*), the decrease of water absorption is an indicator of the starch gelatinization degree, so the greater the percentage of consumption-treated starch, thereby digestibility of the product increases. In this case, with the decrease of the WAI increases WSI, which may indicate an increase in the soluble fraction, resulting from the starch and also other components' degradation. This trend can be observed particularly for the specimens produced at 140°C. Charts courses of WAI and WSI may therefore indicate that in the case of spelt extrusion it can be searched temperature range lower than of the conventional extrusion of corn meal.

With the increase in the content of spelt in the mixture it was also observed increase in water activity (Fig. 7), which also can be observed in all settings of the process. The increase of this parameter, however, is disturbing, because it can contribute to the development of microorganisms, which in turn may impede the subsequent storage of these products, particularly after the package is opened.

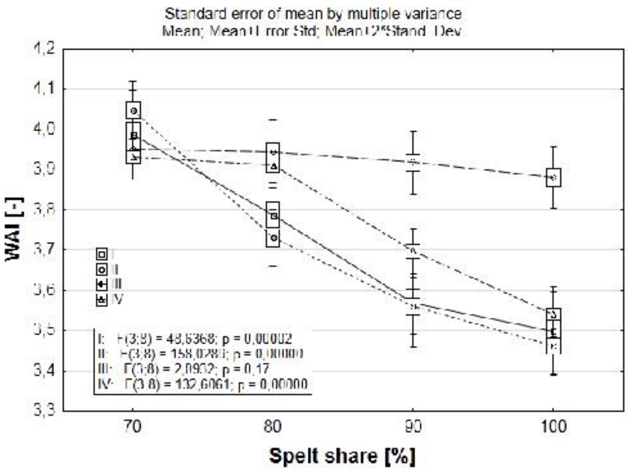

Fig. 3 - Influence of spelt content on WAI changes of extrudates

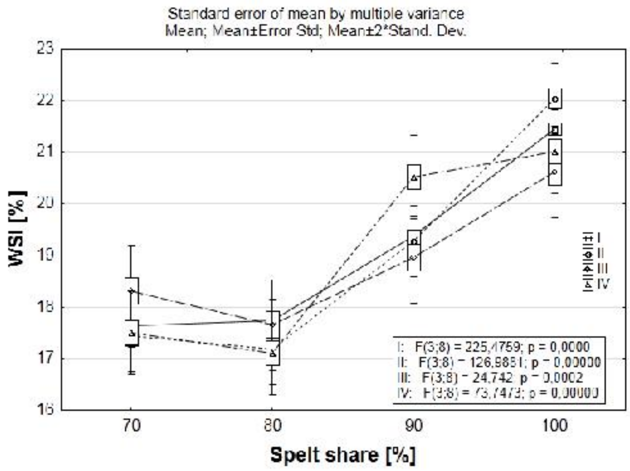

Fig. 4 - Influence of spelt content on WSI changes of extrudates

The increase in the content of spelt in a mixture also caused a reduction in hardness of extrudates (Fig. 5), which clearly could be observed with the use at the process temperature of 140°C. Among the tested samples difference between the hardest sample and the sample with the lowest strength was about 5N. Together with the spelt content in the mix, however, it was observed an increase in the total work "Area" needed to puncture the sample (Fig. 6).

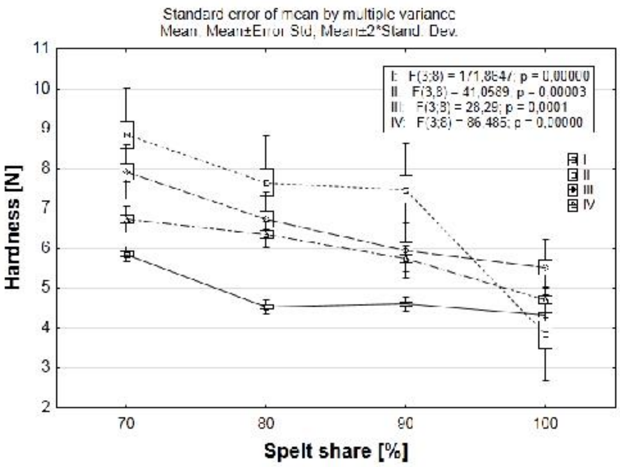

Fig. 5 - Influence of spelt content on hardness changes of extrudates

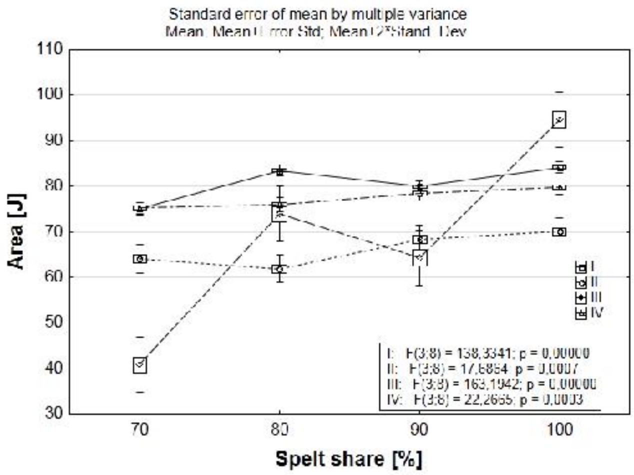

Fig. 6 - Influence of spelt content on "Area-total work" of extrudates

The hardness of the extrudates is in turn highly correlated to the density. It was found at the setting process I, III, IV (0.844, 0.919, and 0.891). Such parameters show that addition of spelt may considerably affect the performance of the textural parameters of extrudates in mixes with e. g. corn.

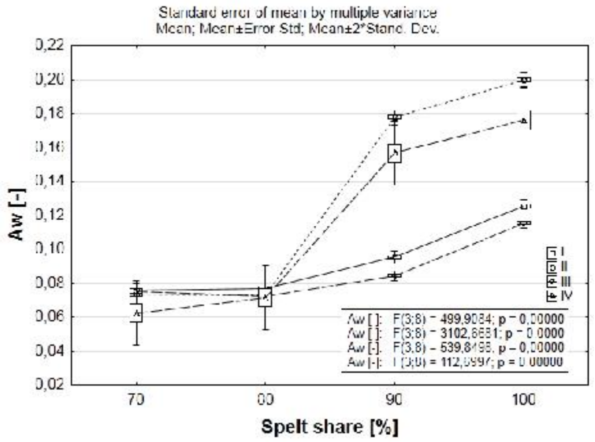

Fig. 7 - Influence of spelt content on water activity Aw of extrudates

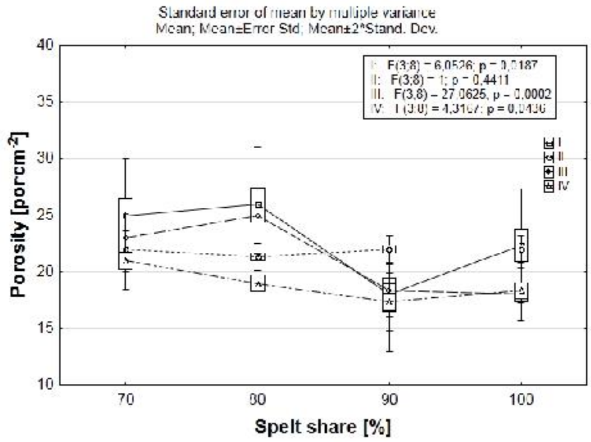

Fig. 8 - Influence of spelt content on porosity changes of extrudates

Together with spelt content the porosity of extrudates slightly reduces its values (Fig. 8), so that the amount of air voids in cm^2 was the smallest for extrudates involving 100% spelt. The same samples obtained at 120°C had a porosity higher than the ones generated at the temperature of 140°C. In the higher screw speed range III and IV porosity strongly correlates with parameters such as Aw (-0.672) and Area (-0.74).

Less than that of corn extrudates porosity is not positive feature of such products. There may also be a link between extrudates obtain with a lower density and a larger expansion (in this case no significant correlation was found). The literature research shows that more fine pores are far more positively perceived by consumers. Studies of this type are, however, subjective experiments, because in the case of the analyzed samples this thesis cannot be unambiguously confirmed without performing sensory analysis, planned in other studies.

CONCLUSIONS

The results of research and literature analysis indicate that spelt is a perspective grain which despite the weaker baking properties compared to the typical varieties of wheat can be a very interesting and, at the same time, healthy raw material for the production of various food products. It was found that spelt is a very good material for baro-thermal extrusion process, and the quality parameters of the products obtained do not differ significantly from products with a high proportion of corn.

The use of raw materials such as spelt to produce the typical snacks or crispy bread can reduce the impact of spelt on its poor baking properties. Despite the clear differences in the quality parameters in products containing spelt, the results for the largest content of spelt are satisfactory, and it can be used as a basic component of the mixture, e. g. in combination with corn or other starchy raw materials.

REFERENCES

[1] Alvarez-Martinez L., Kondury K., P., Harper J. M., (1988), A general model for expansion of extruded products. *Journal of Food Science,* Vol. 53, pp.609-615;

[2] Abdel-Aal, El-Sayed M., Rabalski I., (2008), Effect of baking on nutritional properties of starch in organic spelt whole grain products. *Food Chemistry,* Vol. 111(1), pp.150-156;

[3] Anderson R. A., Conway H. F., Pfeifer V. F., Griffin E. L. (1969), Gelatinization of corn grits by roll and extrusion cooking. *Cereal Science Today, Vol.* 14(1), pp.4-12;

[4] Bonafaccia G., Galli V., Francisci R., Mair V., Skranbanja V., Kreft I., (2000). Characteristics of spelt wheat products and nutritional value of spelt wheat based bread. *Food Chemistry,* Vol. 68, pp.437–441;

[5] Borkowska B., Robaszewska A., (2014), Roasted and Unroasted Buckwheat Groats (Kasza gryczana prażona i nieprażona), *Food Industry,* Vol. 68, pp.36-38;

[6] Choszcz D. J., Konopka S., Zalewska K., (2010), Characteristics of physical properties of selected varieties of spelt, *Agricultural Engineering*. Vol. 4 (122), pp.23-28;
[7] Ekielski A., Majewski Z., Żelaziński T., (2007), Effect of extrusion conditions on physical properties of buckwheat –maize blend extrudate. *Polish Journal of Food and Nutrition Sciences.* Vol. 57, Issue 2(A), pp.57-61;
[8] Ekielski A., (2011), Effect of selected parameters of double-screw extruder operation on fractal dimensions of the extrudate. *Annals of Warsaw University of Life Sciences-SGGW. Agriculture,* Vol. 57, pp.41-47;
[9] Escarnot E., Agneessens R., Wathele B., Paquot M., (2010), Quantitative and qualitative study of spelt and wheat fibers in varying milling fractions. *Food Chemistry.* Vol. 3 (122), pp. 857-863;
[10] Frączek J., Reguła T., (2010), Method of evaluation of susceptibility of spelt grains to mechanical damages during the threshing process, *Agricultural Engineering,* Vol.4 (122), pp.51-58;
[11] Kim J.H., Tanhehco E.J., Ng, P.K.W., (2006), Effect of extrusion conditions on resistant starch formation from pastry wheat flour, *Food Chemistry,* Vol. 99, pp.718–723;
[12] Marconi E., Carcea M., Graziano M., Cubadda R. (1999), Kernel properties and pasta-making quality of five European spelt wheat (Triticum spelta L.) cultivars, *Cereal Chemistry,* Vol. 76, pp.25–29;
[13] Marconi E., Carcea M., Schiavone M., Cubadda R., (2002), Spelt (Triticum spelta L) Pasta quality: combined effect of flour properties and drying conditions, *Cereal Chemistry,* Vol. 79, pp.634–639;
[14] Pierogiovanni A.R., Laghetti G., Perrino P., (1996), Characteristics of meal from hulled wheats (*Triticum dicoccon Schrank and T. spelta L.*): an evaluation of selected accessions, *Cereal Chemistry,* Vol. 76, pp.732–735;
[15] Radomski G., Bać A., Mierzejewska S., (2007), A comparative assessment of baking value of wheat flour and German wheat flour, *Agricultural Engineering,* Vol. 5, Issue 93, pp.369-374;
[16] Ruibal-Mendieta N.L., Delacroix D.L., Meurens, M., (2002), A comparative analysis of free, bound and total lipid content on spelt and winter wheat whole meal, *Journal of Cereal Science,* Vol. 35, pp.337–342;
[17] Sacchetti G., Pinnavaia G. G., Guidolin E., Dalla Rosa M., (2004), Effects of extrusion temperature and feed composition on the functional, physical and sensory properties of chestnut and rice flour-based snack-like products, *Food Research International,* Vol. 37, Issue 5, pp.527-534;
[18] Skrabanja V., Kovac B., Golob T., Elmståhl H. G. M. L., Björck I. M. E., Kreft I., (2001), Effect of spelt wheat flour and kernel on bread composition and nutritional characteristics, *Journal of Agricultural and Food Chemistry,* Vol. 49, pp.497–500, PubMed;
[19] Yuan-Yuan Wang, Krittika Norajit, Mi-Hwan Kim, Young-Ho Kim, and Gi-Hyung Ryu, (2013), Influence of Extrusion Condition and Hemp Addition on Wheat Dough and Bread Properties. *Food Sci. Biotechnol,* Vol. 22, Issue S, pp.89-97, Springer/Korea;
[20] Żelaziński T., Ekielski A., Zdanowska P., Florczak I, (2014a), The effect of ultrasound treatment on selected maize and buckwheat extrudates parameters, *INMATEH - Agricultural Engineering,* Vol. 43, Issue 2, pp.127-136, Bucharest/Romania;
[21] Żelaziński T. ,Ekielski A., Florczak I., (2014b), The vision system usage as data source for statistical process control in the food extrusion, *INMATEH - Agricultural Engineering,* Vol.44, Issue 3, pp.111-120, Bucharest/Romania.