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VARIABILITY OF GEOMETRICAL PROPERTIES, SURFACE COLOR AND PHENOLIC COMPOUNDS CONTENT OF COMMERCIAL ROASTED BUCKWHEAT GROATS

This study was aimed at evaluating commercial roasted buckwheat groats for their organoleptic and geometrical traits, color and content of phenolic compounds. An attempt was also undertaken to correlate the achieved values of the analyzed parameters. The shape, sizes and color (HIS model) were determined using Digital Image Analysis (DIA), whereas the content of phenolics was assayed spectrophotometrically with the Folin-Ciocalteu method. High variability was noted in projection area and length of seeds. In turn, seed circularity was the trait with the lowest variance coefficient. The analyzed groats differed also in color, which may be due to differences in the size of seeds subjected to the roasting process. The low variability was also found in the case of free phenolics content. Finally, the study demonstrated a positive correlation between buckwheat seed surface and the content of phenolic compounds, which may be caused by a correlation between seed size and roasting time.
Keywords: *roasted buckwheat groats, size, color, phenolic compounds.*

INTRODUCTION

Buckwheat (*Fagopyrum esculentum* Moench), classified as a pseudocereal, is a crop traditionally grown in Asia and Europe. It is characterized by a short vegetative season (70–90 days), adaptation to cold and humid climate, and no need for the use of plant protection agents. It owes its growing popularity to a high nutritive value as it is a rich source of B-group vitamins (B_1, B_2, B_6) and minerals: potassium, phosphorus, calcium, magnesium, iron and zinc, as well as to a well-balanced amino acid composition. In addition, it does contain gluten, hence it may be used by celiac patients. Health benefits that stem from the consumption of buckwheat products are due to their natural antioxidants, including tocopherols and phenolic compounds, i.a. flavonoids and phenolic acids. The following flavonoids have been identified in buckwheat seeds: rutin, orientin, vitexin, quercetin, isovitexin, isoorientin, kaempferol-3-rutinoside, and catechin. In turn, phenolic acids of buckwheat include: protocatechuic, vanilic, syringic, ferulic, and sinapic acids [7, 8, 16, 17]. The antioxidative activity of the seedcoat and hulls of buckwheat was shown to be 2 to 7 times higher than that of barley, triticale or oat [1].

There are many buckwheat-based food products worldwide. In Europe, the most popular are groats, in Japan buckwheat is used to produce pasta, whereas in the United States it is a component of breakfast cereals [4, 17]. The production process of buckwheat groats consists of two stages: dehulling and roasting. After dehulling, the seeds are roasted at a temperature of 100–120°C for 1–2 h [7]. Treatments applied in buckwheat groats production process result in a decrease of flavonoids content, the extent of which is affected by the temperature and duration of the heat treatment [2]. In addition, the roasting contributes to changes in the physical traits of groats like: hardness, size and color. Especially the latter may be indicative of the appropriately conducted roasting process. Investigations conducted so far have demonstrated a correlation between the color and phenolic compounds content in non-roasted [11] and roasted [5] buckwheat groats.

The study presented in this manuscript was aimed at determining differences between commercially-available buckwheat groats in terms of geometrical features, color and the content of phenolic compounds. In addition, an attempt was undertaken to determine correlations between physical traits (color and sizes) and phenolics content.

1. MATERIAL AND METHODS

1.1. Material

The research material consisted of 7 samples of commercially available buckwheat grouts (kasha) from Olsztyn market. All products were characterized by an appropriate expiration date for consumption.

1.2. Experimental methods

Organoleptic assessment of buckwheat groats was performed immediately after opening the packages. The assessment included physical appearance (color and surface regularity), flavor and taste after cooking (time was set according to the manufacturer).

The measurements of groats geometrical features and color of their surface were performed according to Tańska et al. [14] with using a customized personal computer-based digital image analysis system. The digital image analyses were performed for the surface of whole groats. Before analyses the calibration to a standard white reflective plate was done. The images were acquired by a high resolution, low-noise CCD Nikon DXM-1200 color camera (Nikon Inc., Melville, USA) and analyzed using the LUCIA G (Laboratory Universal Computer Image Analysis Laboratory Imaging) ver. 4.8 software (Laboratory Imaging, Prague, Czech Republic). The frame grabber board resolution was 1280 × 1024 pixels. The groats were examined from a distance (lens to object) of 2.5 cm. The light source were BOB OM 100 × 1 (BOB Manufacture, Poland) with 4 × 100 W (60 kLx) fiber lamps (color temperature about 3000 K). Seven geometrical features were measured: length, width, perimeter (projection perimeter), area (projection area) and circularity. The values of these features were calculated automatically by the LUCIA G software. The color surface results are presented in HSI color space (H in range 0–360°, S and I in range of 0–100%). The measurements of geometric features were made for 200 randomly selected seeds from a batch of buckwheat groat.

The content of phenolic compounds (the Folin-Ciocalteu reactive compounds) was determined according to Konopka et al. [6]. The phenolic compounds were extracted twice with an 80% solution of methanol (1:10, m/v). The combined extracts were evaporated to dryness and 0.5 ml of the Folin-Ciocalteu reagent (Merck, Darmstadt, Germany) diluted with water (1:2, v/v), 3 ml of 14% sodium carbonate and 6.5 ml of deionized water was added to each of them. After being mixed, samples were left in the dark for 60 minutes and the absorbance of the solutions was then measured with a Unicam UV/Vis UV2 spectrophotometer (ATI Unicam, Cambridge, UK). The content of phenolic compounds was expressed as mg D-catechin (Sigma-Aldrich, Poznań, Poland) equivalent in 1 g of groats. All analyses were made in triplicates.

1.3. Statistical analysis

Statistical analyses (ANOVA with Duncan test) were performed using a STATISTICA v. 12.5 software (Statsoft, Kraków, Poland). The analyses were performed at a significance level of $p \leq 0.05$.

2. RESULTS AND DISCUSSION

2.1. Organoleptic characteristics of roasted buckwheat groats

The analyzed buckwheat groats differed in color and surface homogeneity (photograph 1, table 1). A noticeably brighter color was found for groats no. 1, which may indicate shorter time and/or lower temperature of roasting. In turn, groats no. 3 and no. 6 were darker, which was indicative of more drastic conditions of the roasting process. In addition, groats no. 3 were characterized by an irregular surface with multiple damages.

All buckwheat groats were characterized by a specific flavor, but perceptible was the roasted flavor of various intensity. The flavor of groats no. 1 and no. 5 was delicate, whereas that of groats no. 3 was slightly burnt. After cooking, the taste of almost all groats was typical of roasted groats. An exception was sample no. 3, the taste of which was bitter and burnt.

Phot. 1. The research material (own photographs)

Table 1. Organoleptic characteristics of roasted buckwheat groats

Sample number	Appearance	Flavor	Taste of cooked groats
1	relatively uniform color, light-brown, smooth surface, without damages	specific, little intensive	specific, delicate
2	uniform brown color, smooth surface, without damages	specific, slightly roasted	specific, slightly bitter
3	uniform brown color, very dark, irregular surface, with multiple damages	specific, perceptible burnt flavor, intensive	bitter, burnt, unpleasant
4	non-uniform color, brown, smooth surface, without damages	specific, relatively intensive	specific
5	non-uniform color, light and dark, brown, regular surface with few damages	specific, little intensive	specific, delicate
6	relatively uniform color, dark-brown, relatively regular surface with few damages	specific, roasted	specific, intensive
7	non-uniform color, light and dark light-brown, relatively regular surface without damages	specific, relatively intensive	specific, delicate

2.2. Geometrical features of roasted buckwheat groats

Figure 1 depicts values of geometrical features obtained for particular groats.

The projection area of the analyzed groats fitted within the range of 7.14 – 8.27 mm^2. The greatest statistical differences were achieved between groats no. 3 (7.14 mm^2) and groats no. 1 (8.27 mm^2) and no. 4 (8.18 mm^2). They differed significantly also in terms of other size parameters, i.e.: circumference, length and width.

Variability analysis of the assayed sizes revealed that the projection area (CV = 5.28%) and length (CV = 4.38%) were the parameters that differentiated the samples to the greatest extent.

A shape parameter determined in this study was circularity, which turned out very uniform in the analyzed samples (CV=0.57%). Its mean value ranged from 0.89 to 0.90, which indicated a high similarity of the projections of individual seeds to a circle.

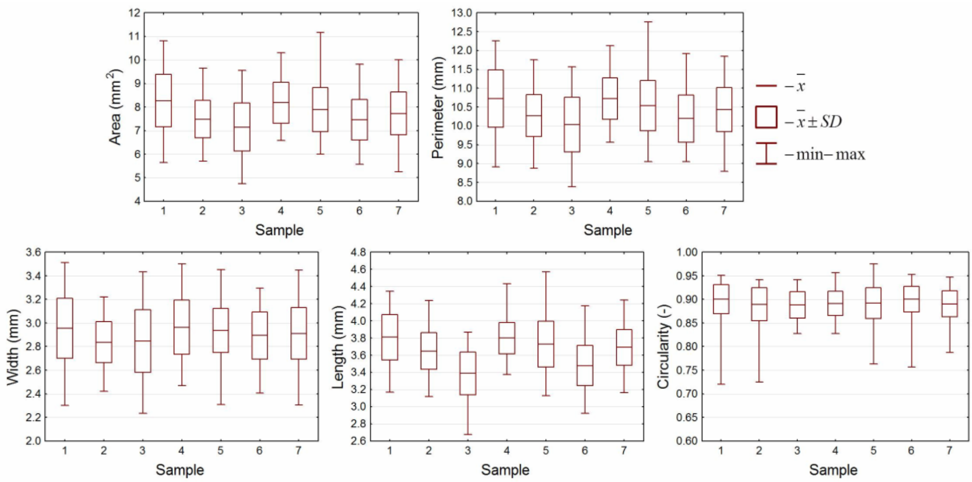

Fig. 1. Geometrical features of roasted buckwheat groats

In summary, it may be concluded that groats no. 1 were the least uniform regarding geometrical features (CV in the range from 3.43 to 13.46%), and that the groats no. 4 were the most uniform in this respect (CV in the range from 3.96 to 10.28%).

Such great differences in size between the groats may result not only from various roasting conditions applied by producers but also from buckwheat species. Lu et al. [9] demonstrated that 1,000-kernel weight of buckwheat seeds may greatly vary from 16.5 g to 39.8 g as affected by the cultivar.

2.3. Surface color of roasted buckwheat groats

The color of buckwheat groats was expressed in the HSI model, wherein the H component denotes hue, S component – saturation and I component – intensity. Results of measurements of these components were presented in Figure 2.

The analyzed groats differed in terms of color. The mean values of the H component ranged from 20.58 to 26.62°. Color saturation (S value) ranged from 46.83 to 63.60%, whereas its intensity from 31.16% to 56.00%. The range between the extreme values indicates great differences between the investigated groats and the differences in color noted between the groats originating from various producers were found to be statistically significant.

The variability analysis of color components revealed that the examined samples were differentiated to the greatest extent by the component I (CV = 19.80%). In a study conducted by Klepacka [5], the change of buckwheat groats color during roasting was best described by the component S, the values of which were increasing as affected by both dehulling process and roasting of buckwheat seeds.

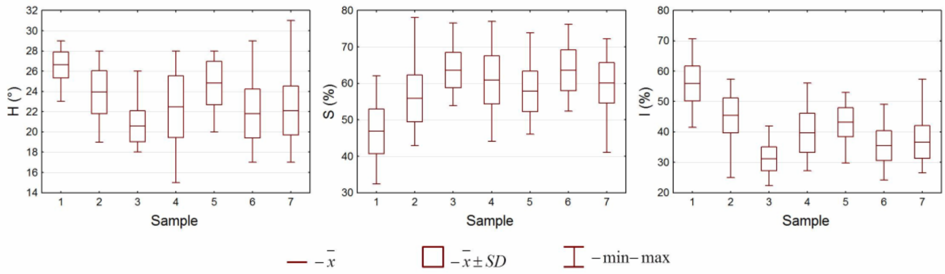

Fig. 2. Color of roasted buckwheat groats

Large differences in color within a sample of groats may be explained by their inhomogeneity in terms of sizes. It confirms results obtained by Wronkowska et al. [15], who analyzed the effect of roasting duration on buckwheat groats color. They demonstrated that the brightness of groats was decreasing along with extension of heat treatment, however the particles with smaller sizes required shorter roasting time. It may, therefore, be concluded that if particles of various sizes are roasted for the same period of time, they differ in color brightness once the heat treatment is completed.

2.4. Phenolic compounds content in roasted buckwheat groats

Figure 3 presents contents of phenolic compounds extracted with 80% methanol from the analyzed samples of roasted buckwheat groats. The contents of phenolics differed and ranged between 2.21 and 2.86 mg/g groats. The differences were, however, statistically insignificant. It means that the production process of buckwheat groats in various processing plants had no significant effect on the content of free phenolic compounds in the groats.

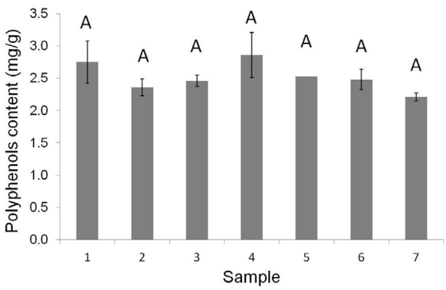

Fig. 3. Content of phenolic compounds in roasted buckwheat groats
A – no significant difference at $p < 0.05$

The lack of significant differences between commercial roasted buckwheat groats was also demonstrated by Majkowska et al. [10].

Many works have shown, however, that heat treatments induce chemical changes of food components. They afflict also bioactive compounds that determine the antioxidative activity of a food product [17]. Zhang et al. [16] investigated how technological processes, i.a. roasting, affected contents of flavonoids and polyphenols and the antioxidative activity of flour from tartary buckwheat (*Fagopyrum tataricum* Gaertn.). The content of flavonoids (expressed in rutin equivalents) and polyphenols (expressed in gallic acid equivalents) in untreated flour reached 0.992 mg/g and 0.823 mg/g, respectively. The heat treatment at 80°C for 20 min caused a statistically significant decrease in the content of flavonoids. The changes intensified along with temperature increase (from 80 to 120°C) and roasting time elongation (from 20 to 40 min). In turn, the content of polyphenols decreased statistically significantly (by 9%) already upon heat treatment at 120°C for 40 min [16].

In contrast, Şensoy et al. [12] demonstrated no correlation between the content of phenolic compounds and heat treatment. They conducted their study on dark (with fragments of hulls) and light (from hulless buckwheat) flour from common buckwheat (*Fagopyrum esculentum* Moench) and demonstrated that the content of polyphenols determined colorimetrically with a Folin–Ciocaltea reagent did not change statistically significantly after roasting at 200°C for 10 min [12].

2.5. Correlations between phenolic compounds content, geometrical features and surface color of roasted buckwheat grots

Table 2 presents results of a correlation analysis conducted between the analyzed parameters, i.e. size, shape, color and content of phenolic compounds.

A positive correlation (r = 0.67) was demonstrated between surface area of buckwheat seeds and phenolics content. It indicates that the content of free phenolic compounds increases along with an increasing size of the seeds. Noteworthy is also the impact of the roasting process. Duration of roasting is set for the entire batch of seeds containing both small and large seeds. It means faster heating and greater changes in the small than in the large seeds.

Steadman et al. [13] studied the content of polyphenols in various seed fractions of common buckwheat (*Fagopyrum esculentum* Moench). They demonstrated the highest concentration of these compounds in the seedcoat (15.48 mg catechin/g), and the least one in fancy flour (1.13 mg/g). Similar results were achieved by Guo et al. [3], who analyzed tartary buckwheat (*Fagopyrum tataricum*). The seedcoat contained over 9 times more phenolic compounds compared to the fancy flour. In addition, they demonstrated that ca. 98% of phenolics occurred in the free form. Taking into account such a localization of phenolic compounds in the seeds, it may be concluded that the size of seeds will affect phenolics content expressed per weight unit.

Table 2. Pearson linear correlation coefficient between geometrical features, color and phenolics compounds content of roasted buckwheat groats

	A	P	L	W	C	H	S	I	PC
A	–	–	–	–	–	–	–	–	–
P	0.99*	–	–	–	–	–	–	–	–
L	0.94*	0.96*	–	–	–	–	–	–	–
W	0.91*	0.90*	0.76*	–	–	–	–	–	–
C	0.38	0.28	0.15	0.42	–	–	–	–	–
H	0.70	0.68	0.73	0.47	0.44	–	–	–	–
S	–0.64	–0.61	–0.66	–0.36	–0.42	–0.93*	–	–	–
I	0.70	0.68	0.73	0.42	0.46	0.97*	–0.97*	–	–
PC	0.67	0.64	0.46	0.67	0.38	0.36	–0.32	0.41	–

Abbreviations: A – area, P – perimeter, L – length, W – width, C – circularity, H – H value, S – S value, I – I value, PC – phenolics compounds content
* – statistically significant at $p \leq 0.05$.

No statistically significant correlations were demonstrated between color components and the size and phenolic content of seeds. Noteworthy is, however, that coefficients of correlation between the surface area and length of seeds and values of color components H and I were high and ranged from 0.70 to 0.73. It is indicative of a moderate correlation between these parameters which may be caused by the fact that a high temperature applied during roasting has a more destructive effect on the smaller particles, which is manifested in their more brown (lower values of H component) and less intensive color (lower values of I component). In turn, negative values of coefficients of a correlation between component S and sizes of groats point to a greater color saturation of the fine-grained buckwheat groats.

Results obtained by Wronkowska et al. [15], who studied the effect of roasting time on buckwheat groats color, confirmed that the brightness of groats color was decreasing along with elongated time of heat treatment. Particles with smaller sizes require shorter roasting time and, hence, if particles of various sizes are roasted for the same period of time, they differ in color brightness once the heat treatment is completed. Likewise in our study, the cited authors showed no statistically significant correlation between values of the analyzed color parameters and the content of polyphenols in buckwheat groats. In contrast, Ikeda et al. [4] demonstrated correlations between values of L* and b* color components and polyphenolics content.

SUMMARY

Considerable differences were demonstrated between the analyzed buckwheat groats in both geometrical features, color parameters and phenolics content. The greatest fluctuations were observed in projection area as well as length and width of seeds. Also in the HIS model describing the color depending on the sample, all color components were characterized by a high variability. The analyzed commercial groats differed also in the content of phenolic compounds, however differences observed were statistically insignificant. It may, therefore, be concluded that the production process of buckwheat groats in various processing plants had no significant effect on their content of free phenolics. The correlation analysis showed no statistically significant correlations between color components and sizes and phenolics content.

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