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IMPACT OF STORAGE CONDITIONS ON THE INSTRUMENTAL COLOUR OF BUCKWHEAT PRODUCTS FOR MEAT INDUSTRY APPLICATIONS

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Abstract: Buckwheat is one of the functional pseudocereals rich in antioxidants, nutrients, bioactive compounds, and phytochemicals. Colour represents one of the most important sensory parameters in the quality assessment of the meat products. The aim of this study was to determine the possible effect of 9-month artificial aging storage at 40 ± 2 °C on the change in instrumental colour of buckwheat products used in the meat industry. In the CIE L*a*b* system, L*, a*, and b* coordinates are used to specify the data of instrumental colour properties. The results were statistically processed by two-way ANOVA ($P<0.001$) and Tukey's Honestly Significant Difference post-hoc tests ($P<0.05$). Storage and product type (and their interaction) factors significantly influenced instrumental colour. During storage, significant differences were observed between the time points (0, 3, 6, and 9 months) in flour, with trends of decreasing lightness (L*) and increasing red (a*) and yellow (b*) colour intensity values. Regarding product type, significantly higher L* values were observed in flour, while a* values were higher in grains. Except for the 3rd month, b* values did not show significant differences. The insights gained in this study may indicate the further application of stored buckwheat flour and grains in obtaining technologically justified and colour-sensory acceptable meat end-products for consumers.

Key words: colour, buckwheat, flour, grains, storage, meat products

Introduction

In the era focused on nutritionally justifiable and health-beneficial food, the spotlight falls on functional food enriched with bioactive ingredients.

Pseudocereals, with buckwheat as a notable example, stand out in this category. Buckwheat is a good source of nutrients, bioactive components, phytochemicals, and antioxidants (Salejda et al., 2022; Sofi et al., 2023). Traditionally, buckwheat products such as grains, seeds, and flour are usually consumed as breakfast cereals and bakery products, or incorporated into enriched products such as bread, dough, pancakes, noodles, honey, sprouts, tea, and snacks (Devrajan et al., 2018; Małgorzata et al., 2018; Sofi et al., 2023).

In recent years, there has been a growing trend in utilizing buckwheat ingredients in processed meat products, marking a significant development in the modern meat industry. Numerous studies have demonstrated that incorporating buckwheat raw materials (grains, flour, husks) into meat product recipes and technologies can effectively enhance various physical and chemical, functional, technological, structural, mechanical and organoleptic parameters of combined meat products, such as semi-smoked sausages, frankfurter-type sausage, pork meatballs, horsemeat patties, chicken patties etc. (Hęś et al., 2017; Salejda et al., 2022; Atambayeva et al., 2023; Yessengaziyeva et al., 2023). Moreover, buckwheat and its products offer numerous health-related benefits, such as hypoglycemic, anticancer, hypocholesterolemic, anti-hypertensive, and anti-inflammatory properties, significantly enhancing their agricultural, industrial, and pharmaceutical utility value (Fotschki et al., 2020; Mondal et al., 2021; Salejda et al., 2022; Sofi et al., 2023).

Given its nutritional and functional importance, storing large quantities of post-harvest grains for extended periods is essential. However, prolonged storage negatively impacts both the quality and nutritional attributes of grains (Rakić et al., 2014), as elevated temperatures during storage could lead to the loss of soluble sugars (Zia-Ur-Rehman, 2006). Similarly, storage time is a factor that significantly affects flour quality, with higher temperatures accelerating deterioration reactions, while low-temperature (e.g., −20 °C) conditions have a positive effect on storage stability (Lancelot et al., 2021). During storage, grain quality inevitably deteriorates due to degradative changes in its biological, physical, and chemical properties. These changes negatively affect the quality of flour obtained from the grain, including its colour as a sensory property (Ping-Ping et al., 2019; Suzuki et al., 2020; Rakić et al., 2023).

In the meat industry, long-term storage and high temperature adversely impact the sensory and physicochemical characteristics of meat products due to accelerated proteolysis, glycolysis or hydrolytic, and oxidative processes of adipose tissue (Augustyńska-Prejsnar et al., 2023). The modulated sugar profile of buckwheat-flour-enriched meat products could also influence shelf life. For instance, the increase in reducing sugars resulting from the hydrolysis of buckwheat-flour-enriched products by either meat or microbial enzymes alters the quantity and composition of sugars available for further microbial proliferation

during storage. This can potentially result in off-odors, negatively impacting another sensory characteristic - smell (Mendiolea et al., 1995).

On the other hand, preserving of quality and nutritional traits of buckwheat products and meat products could be managed for a prolonged period with appropriate storage conditions (Fleurat-Lessard, 2002; Wagh et al., 2015; Augustyńska-Prejsnar et al., 2023), which would also keep the colour unchanged for a certain time. Many papers have examined the effects of storage conditions, such as temperature variations and prolonged storage duration, on the colour changes of flour and grains in various cereals, as well as in various meat and meat products. However, limited attention has been given to the impact of these factors on buckwheat material and meat products combined with it. The colour of meat originates from myoglobin (or its three forms), and is further influenced by lipid oxidation and the subsequent formation of oxidation products, which can further affect myoglobin. Conversely, buckwheat contains flavonoids, pigments responsible for its coloration (Wang et al., 2021; Atambayeva et al., 2023). It is well known that changes in colour provide information on the extent of browning reactions (Maillard reaction, pigment degradation, caramelization, etc.) or lipid degradation and oxidation, which are mostly but not always caused by thermal processes (Anberbir et al., 2023; Atambayeva et al., 2023). Storage conditions, particularly temperature, and duration of storage, have a significant impact on the colour of the flour (Muneer, 2015). Moreover, antioxidants present in buckwheat products, such as polyphenolic compounds, can mitigate the development and slow down the intensity of chemical transformations associated with lipid degradation, oxidation, or pigment oxidation in meat products by scavenging free radicals, thereby impeding color changes. (Wagh et al., 2015; Salejda et al., 2022; Atambayeva et al., 2023).

These findings are part of the ongoing investigation into the properties of buckwheat products and their application in meat products. Thus, in this study, the impact of storage conditions on buckwheat flour and grains was observed from the perspective of their possible further use in obtaining technologically justified and colour-sensory acceptable meat end-products for consumers.

Materials and Methods

Buckwheat (Novosadska variety) harvested in 2022 at the technological maturity stage was used for research. The obtained grains were cleaned of impurities and damaged grains. Sampling was performed according to ISO 24333 (2009), and a 2 kg sample of freshly harvested buckwheat grain was brought to the laboratory. A detailed description of sample storage has been previously reported (Ping-Ping et al., 2019). Briefly, the grain sample was equally distributed into eight

closed plastic containers of the same volume. Six containers were placed in a drying oven Digitheat-TFT (J.P Selecta, Barcelona, Spain) at a temperature of 40 ± 2 °C with thermoregulation and common relative humidity for periods of 3, 6, and 9 months. At the end of each period, two containers were taken, their contents mixed, and a sub-sample (about 0.5 kg) was formed. Half of this sub-sample was kept as whole grains, while the other half was crushed and ground at a speed of 20.000 rpm using a laboratory mill A10 (IKA Works Inc., NC, Wilmington, USA) to obtain flour with a particle size of 1 mm for analysis. Both flour and grain samples were prepared in triplicate.

The instrumental colour was measured at five opposite points around each flour and grain sample on chromameter CR-410 (Konica Minolta Sensing Inc., Osaka, Japan). Diffuse light D-65 was applied, as it represents average daylight that correlated with a colour temperature of approximately 6 500 K. The standard angle of 2 degrees of shelter and 50 mm aperture of the measuring head were used. The results were expressed in CIE L*a*b* system (CIE Colorimetry, 1986) as L* (psychometer light), a* (psychometer tone) and b* (psychometer chroma), where L* value indicates the lightness from black (0) to white (100), a* value varies from green (-) to red (+), and b* value ranges from blue (-) to yellow (+). Before measurement, chromameter was calibrated regarding the white standard (tile).

To interpret the instrumental colour results of experiment, the obtained data were presented as mean ± standard deviation (M±SD) and statistically processed. The two-factor analysis of variance (two-way ANOVA, $P<0.001$) was used to evaluate the effect of storage time, product type and their interaction, and Tukey’s HSD (Honestly Significant Difference, $P<0.05$) post-hoc test to determine differences between means, applying Statistica 12.5 software (StatSoft, Inc., Tulsa, OK, USA).

Results and Discussion

Table 1 presents the values of determined instrumental parameters of buckwheat colour in relation to storage time and product type factors. Notably, both storage time and product type, as well as their interaction, significantly affected instrumental colour parameters ($P<0.001$). During storage, there were no significant changes in any instrumental colour parameters of the buckwheat grain. Moreover, progressive changes were noted with increasing storage time in buckwheat flour for all observed instrumental colour parameters. Significant alterations were revealed by product type in all instrumental colour parameters, except for yellow tone parameters (except for the third month).

Table 1. Changes on buckwheat instrumental colour parameters in relation to storage time (S), product type (P), and their interaction (S×P)

n=3 (five points each)	Product type	Months				Level of significance		
Parameters		0 month	3 months	6 months	9 months	S	P	S×P
L*	grains	32.68 ± 0.764^{A}	31.60 ± 0.694^{A}	31.67 ± 0.376^{A}	32.53 ± 0.781^{A}	***	***	***
	flour	73.84 ± 0.208^{bB}	71.95 ± 0.945^{bB}	69.17 ± 1.235^{aB}	76.17 ± 0.497^{cB}			
a*	grains	5.41 ± 0.074^{B}	5.54 ± 0.152^{B}	5.72 ± 0.240^{B}	5.77 ± 0.191^{B}	***	***	***
	flour	2.00 ± 0.049^{aA}	3.01 ± 0.064^{cA}	2.64 ± 0.040^{bA}	2.43 ± 0.021^{bA}			
b*	grains	9.21±0.294	8.97 ± 0.265^{A}	8.93±0.302	9.47±0.329	***	***	***
	flour	8.80 ± 0.100^{a}	11.26 ± 0.071^{cB}	9.09 ± 0.100^{ab}	9.69 ± 0.121^{b}			

$^{a, b, c}$ Means within the same row with different superscripts differ significantly (P<0.05); $^{A, B}$ Means within the same column with different superscripts differ significantly (P<0.05); *** P<0.001

As the storage time increased, the flour in the sections exhibited a decreasing trend in lightness. However, a statistically significant difference (P<0.05) was observed at 6 months and beyond. Additionally, L* on the 9th month was significantly different from all others. This inconsistency in the decreasing pattern could possibly be attributed due to the mechanically easier shredding of the more dried shell and greater homogeneity of the sample thus prepared. Product type affects lightness changes. Throughout the storage period, buckwheat grains consistently demonstrated significantly lower lightness compared to the results obtained in flour (P<0.05). In contrast to the decrease in lightness, the a* and b* values of flour showed a progressive increase with the passage of storage time. Compared to the start of storage, redness significantly increased (P<0.05) until the end of storage, but without significant changes after 6 months. A similar trend was observed in the yellow tone parameter during storage.

The effect of product type on a* remains consistent throughout the storage period, with significantly higher values (P<0.05) in buckwheat grains compared to flour. On the other hand, there were no significant differences in b* values between buckwheat grain and obtained flour, except for the 3rd month, which exhibited a significantly increased yellowness in the instrumental colour of the flour.

Our study aligns with analysis conducted by several researchers (Muneer, 2015; Anberbir et al., 2023), highlighting the impact of various natural processes, especially of the chemical type, such as the Maillard reaction, pigment degradation, and caramelization, known to collectively contribute to browning. These processes are notably heightened by extended storage duration and thermal effects, leading to significant alterations in the instrumental colour parameters. Additionally, Muneer

(2015) reports that increasing the storage time by one more day leads to a decrease in the colour value of the stored flour, which agrees with our L* values.

For our further research, it can be assumed that combining buckwheat and meat products can lead to the instrumental colour change in the final product, mainly by decreasing L* and increasing a* and b* values, with significant control of the applied formulation. In combined meat products, Atambayeva et al. (2023) reported that the addition of buckwheat and its flour to horsemeat and chicken patties resulted in a lower L* value and slightly higher a* and b* values, while during storage, L* values decreased slowly, whereas a* and b* showed higher values. All value changes could indicate the preservation of product colour during the prolonged storage time, due to the presence of phenolic compounds that stabilizes oxymyoglobin and delays its deterioration. On the contrary, the increasing addition of buckwheat husks in frankfurter-type sausage (3% or more) resulted in a decrease in L* and b* values, which sets colour change at a lower level of consumer acceptability, but with minimal changes in colour-sensory properties during 2-weeks of storage period (Salejda et al., 2022). Similarly, Yessengaziyeva et al. (2023) stated that incorporating buckwheat flour in semi-smoked sausage (12% or more) made meat colour unsatisfactorily desirable and less attractive.

Conclusion

Based on the obtained results, which form a part of the ongoing investigation into the application of buckwheat products in the meat industry, it can be concluded that storage time, product type, and their interaction influenced the instrumental colour of buckwheat flour and grains. During storage, a trend of decreasing lightness and increasing intensity of red and yellow colours was observed in the flour over intervals of 0, 3, 6, and 9 months. According to product type, significantly higher L* and certain b* values were found in flour, while higher a* values were observed in grains. These results provide valuable guidelines for meat producers and the meat processing industry regarding the management and storage conditions of buckwheat flour and grains. The inclusion of buckwheat in meat products can impact the visual appear and overall attractiveness of meat end-products to consumers.

Uticaj uslova skladištenja na instrumentalnu boju proizvoda od heljde za primenu u industriji mesa

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Rezime

Heljda je jedna od funkcionalnih pseudožitarica bogata antioksidansima, hranljivim materijama, bioaktivnim jedinjenjima i fitohemikalijama. Boja predstavlja jedan od najvažnijih senzornih parametara u proceni kvaliteta proizvoda od mesa. Cilj ovog istraživanja je bio da se utvrdi mogući uticaj 9-mesečnog veštačkog starenja u skladištu na 40 ± 2 °C na promenu instrumentalne boje proizvoda od heljde koji se koriste u mesnoj industriji. CIE L*a*b* sistem sa L*, a* i b* koordinatama je bio korišćen za specifikaciju podataka o svojstvima instrumentalne boje. Rezultati su bili statistički obrađeni testovima dvofaktorska ANOVA ($P<0.001$) i Tukey-jev Honestly Significant Difference post-hoc ($P<0.05$). Faktori skladištenje i tip proizvoda (i njihova interakcija) su značajno uticali na instrumentalnu boju. Tokom skladištenja uočene su značajne razlike između preseka (0, 3, 6 i 9 meseci) u brašnu, sa trendovima opadanja svetloće (L*) i povećanja vrednosti intenziteta crvene (a*) i žute (b*) boje. Prema tipu proizvoda, značajno veće vrednosti L* su bile u brašnu i a* u zrnu, dok vrednosti b*, sa izuzetkom u 3. mesecu, nisu bile značajno različite. Uvidi stečeni u ovoj studiji mogu ukazati na dalju primenu uskladištenog heljdinog brašna i zrna u dobijanju tehnološki opravdanih i boja-senzorno prihvatljivih krajnjih proizvoda od mesa za potrošače.

Ključne reči: boja, heljda, brašno, zrna, skladištenje, meso

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Conflict of interest
The authors declare no conflict of interest.

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