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## KEY ASPECTS OF INSTRUMENTAL COLOUR FOR COMPOSITE BUCKWHEAT EMULSION-TYPE CHICKEN SAUSAGES

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**Abstract:** Buckwheat is one of the traditionally high-quality crops recognized for its high nutritional and functional value. Emulsion-type chicken sausages modified by adding time-different stored buckwheat flours (FB0, FB3, FB6, and FB9) were analyzed for instrumental colour parameters ( $L^*$ ,  $a^*$ ,  $b^*$ ,  $C^*$ ,  $h$ ,  $S$ ,  $\Delta E$ ). One-way ANOVA test ( $p < 0.05$ ), followed by Tukey's HSD post-hoc test ( $p < 0.05$ ) were used to analyze the data. Added flour slightly affects  $L^*$ , and significantly  $a^*$  and  $b^*$ , where FB0 was lighter, redder and yellower than the other composite products. A significant decrease in  $C^*$  and increase in  $h$  values caused lower chromatic purity and a more yellow nuance in FB9 (20.65, 45.40). A decrease in  $S$  resulted in the greatest attenuation in overall colour perception at FB6, and FB9. An increase trend of  $\Delta E$  indicating the differentiation of sausages with respect to effect on total colour ( $\Delta E \leq 5.10$ ). The results indicate the potential utilization of long-term stored buckwheat grains (flour) as a functional ingredient and valuable plant-based raw material in the production of composite, technologically justified meat products with sensory acceptable colours for consumers.

**Keywords:** Emulsion-type sausage, Buckwheat, Composite product, Instrumental colour, Storage

### INTRODUCTION

The meat industry is one of the most important branches of the food industry, which requires the continuous introduction of new products, with a special emphasis on modern consumer demands for products enriched with plant ingredients or antioxidants of natural (plant) origin. In the modern meat industry, the addition of plant-based raw materials (cereals, flour, hulls, powder, extracts) to meat product formulations can effectively improve various chemical, nutritional, functional, technological and sensory properties (Yessengaziyeva et al., 2023). For these reasons, formulation development has led to the production of composite products similar to dried fermented or semi-smoked sausages, frankfurter-type sausages, horse meat or chicken patties, pork meatballs (Salejda et al., 2022; Pisinov et al., 2025b).

For human consumption, buckwheat grains are often stored for long periods of time for strategic reasons. Storage conditions determine the preservation of nutritional characteristics for a longer period of time and can affect changes in biological, physical and

chemical properties. There are numerous studies that address this issue (Rakić et al., 2005; Pisinov et al., 2024). These changes negatively affect the quality of flour obtained from the grain, including its colour as a sensory property (Suzuki et al., 2020; Rakić et al., 2024). Lipid degradation negatively affects taste, which reduces the useful value of the grain and its shelf life (McGorin, 2019). In the meat industry, long-term storage and high temperature negatively affect the sensory and physicochemical characteristics of meat products due to accelerated proteolysis, glycolysis or hydrolytic and oxidative processes in adipose tissue.

Many papers have presented the influence of storage conditions, such as temperature variations and extended storage duration, on the colour change of flour and grains in various cereals, as well as in various types of meat and meat products. It is known that colour changes provide information about the degree of browning-darkening reactions (the 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; Pisinov et al., 2025a). Some studies have shown that up to 80% of consumer decisions are influenced by colour, and 93% of customers reported that colour (visual appearance) is a primary aspect of their purchasing decisions (Khandelwal et al., 2024). Buckwheat-enriched meat products, besides a favourable nutritional profile, may exhibit altered sensory features, specifically color, that reduce the quality attributes of overall acceptability for consumers (Pietrzak et al., 2022). These colour changes can be even more pronounced when green-coloured buckwheat flour is used in the production of thermally processed emulsion-type sausages (Wagh et al., 2015; Lee et al., 2018; Atambayeva et al., 2023; Yessengazyeva et al., 2023).

The aim was to monitor the instrumental colour changes ( $L^*$ ,  $a^*$ ,  $b^*$ ,  $C^*$ ,  $h$ ,  $S$  and  $\Delta E$ ) of produced composite (enriched) product after adding buckwheat flour obtained from buckwheat stored for 0, 3, 6 and 9 months into emulsion-type chicken sausages.

## **MATERIAL AND METHODS**

### **Preparation of Buckwheat Flour and Production of Composite Product**

Buckwheat (Novosadska variety) used in this research, locally important as an alternative crop and pseudocereal, was harvested in 2022 at technological grain maturity. Raw grains are cleaned of impurities and damaged grains. Sampling was carried out according to the ISO 24333 (2009) method, at 8 locations at an interval of 30 days, forming a representative amount of 4 kg of buckwheat grain sample (approximately 0.5 kg from each of the 8 sampling locations). In the laboratory, the grains were evenly distributed into eight samples, six of which were stored in plastic containers for 3, 6 and 9 months in a drying oven (Digitheat-TFT, J.P Selecta, Barcelona, Spain) at a temperature of  $(40 \pm 2)$  °C with controlled thermoregulation and a relative humidity of 50%. At the end of each testing period, a subsample (approximately 0.5 kg) was formed from the two samples, which were crushed and ground in a laboratory mill A10 (IKA Works Inc., NC, Wilmington, USA) at a speed of 20000 rpm, obtaining wholegrain flour of particle size 1 mm. Further, buckwheat flour was used in the production of a composite product vacuum-packed emulsion-type chicken sausages enriched with stored buckwheat.

Emulsion-type chicken sausages were prepared in a meat processing plant “Milan” located in Dobanovci, Belgrade, which specializes in the processing and sale of chicken meat and products. Five sausage treatments were prepared, each in batches of 2 kg, with the formulations shown in Table 1.

Table 1. Composite product formulations (kg)

Composition (kg)/Group	CON	FB0	FB3	FB6	FB9
Mechanically separated meat	1.13	1.07	1.07	1.07	1.07
Buckwheat flour	/	0.06	0.06	0.06	0.06
Chicken skin	0.38	0.38	0.38	0.38	0.38
Ice	0.38	0.38	0.38	0.38	0.38
Ingredients	0.11	0.11	0.11	0.11	0.11

**Ingredients:** 2.00% potato starch, 1.80% salt (with 0.5% NaNO<sub>2</sub>), 0.85% seasoning, 0.80% beef protein, 0.30% stabilizer - complete, 0.10% carrageenan, and 0.01% colour (E120)

The production process was common for industrial production and identical for all treatments. All formulations contain equal amounts of ingredients, except for the added buckwheat flour. The control treatment (CON) was made from mechanically separated chicken meat (MSM) without the addition of buckwheat flour, while in the other treatments was added buckwheat flour stored for 0 (FB0), 3 (FB3), 6 (FB6) and 9 (FB9) months. After production, control and buckwheat-enriched emulsion-type chicken sausages were vacuum packed (with 99.9% vacuum level) and stored at (2 ± 2) °C. Three repetitions of the experiment were conducted.

### Instrumental Color of the Composite Product

Instrumental color was measured at five opposite points of the longitudinal section on each emulsion-type chicken sausage without and with the addition of buckwheat flour on a chromameter CR-400 (Konica Minolta Sensing Inc., Osaka, Japan). Conditions were described by Stajić et al. (2014). The results were expressed in the CIEL\*a\*b\* system (CIE, 1976) following the explanations and formulas described by Pisinov et al. (2025a). The chromameter was calibrated before measurement against a white tile standard (L\* = +97.83, a\* = -0.43, b\* = +1.98). The appearance and colour of composite products, emulsion-type chicken sausage without (control) and with added buckwheat flour stored for 0, 3, 6 and 9 months are presented in Figure 1.

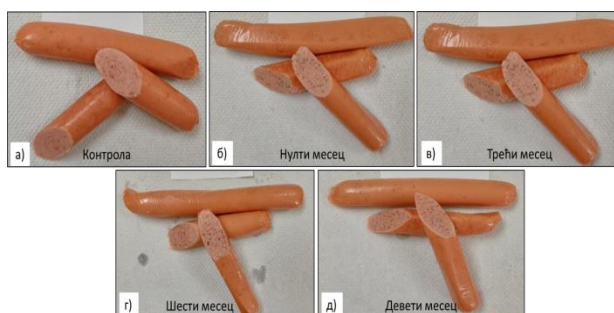


Figure 1. Appearance and colour of composite products (emulsion-type chicken sausage) without (control, (a)) and with added buckwheat flour stored for 0 months (б), 3 months (в), 6 months (г) and 9 months (д).

## Statistical Analysis

To interpret the results of the instrumental colour of the composite product, the obtained data are presented as the mean  $\pm$  standard deviation ( $M \pm SD$ ). The results of the instrumental colour parameters were statistically processed by one-factor analysis of variance (one-way ANOVA,  $p < 0.05$ ) to assess the influence of the composite product formulation and Tukey HSD (Honestly Significant Difference,  $p < 0.05$ ) post-hoc test to determine differences between mean values. Statistical analysis was performed using Statistica 12.5 software (StatSoft, Inc., Tulsa, OK, USA).

## RESULTS AND DISCUSSION

Table 2 shows the values of instrumental colour parameters in relation to different composite products enriched with stored buckwheat. Different formulations of the same type of product significantly affected all instrumental colour parameters ( $p < 0.05$ ). Compared to the CON product, the storage period of buckwheat did not affect  $L^*$  values ( $p > 0.05$ ). However, emulsion-type chicken sausage with 0 months of stored buckwheat flour (FB0) is significantly lighter compared to other composite products. This difference in lightness (darkening) is associated with stored buckwheat grains (flour), as the development of lipid oxidation and Maillard reaction products easily occurs during thermally assisted long-term storage and drying (Pietrzak et al., 2022; Pisinov et al., 2024). Similar to our results, Salejda et al. (2022) found that the addition of 3% and more buckwheat husks in frankfurter-type sausages resulted in a decrease in  $L^*$  values. Yessengaziyeva et al. (2023) noticed that the addition of 12% and more buckwheat flour in semi-smoked sausages made composite product colour unsatisfactorily desirable and more unattractive.

Table 2. Changes in instrumental colour parameters of composite products in relation to the storage period of buckwheat flour added to emulsion-type chicken sausages

Parameters	Product type				
	CON	FB0	FB3	FB6	FB9
$L^*$	59.25 $\pm$ 0.499 <sup>ab</sup>	60.65 $\pm$ 0.467 <sup>b</sup>	58.70 $\pm$ 0.091 <sup>a</sup>	58.95 $\pm$ 0.523 <sup>a</sup>	58.39 $\pm$ 0.876 <sup>a</sup>
$a^*$	19.07 $\pm$ 0.316 <sup>c</sup>	18.57 $\pm$ 0.190 <sup>c</sup>	15.86 $\pm$ 0.092 <sup>b</sup>	15.09 $\pm$ 0.361 <sup>a</sup>	14.50 $\pm$ 0.170 <sup>a</sup>
$b^*$	16.48 $\pm$ 0.454 <sup>b</sup>	16.25 $\pm$ 0.212 <sup>b</sup>	15.22 $\pm$ 0.127 <sup>a</sup>	14.96 $\pm$ 0.285 <sup>a</sup>	14.71 $\pm$ 0.112 <sup>a</sup>
$C^*$	25.21 $\pm$ 0.537 <sup>c</sup>	24.67 $\pm$ 0.275 <sup>c</sup>	21.98 $\pm$ 0.147 <sup>b</sup>	21.25 $\pm$ 0.456 <sup>ab</sup>	20.65 $\pm$ 0.193 <sup>a</sup>
$h$	40.83 $\pm$ 0.307 <sup>a</sup>	41.18 $\pm$ 0.159 <sup>a</sup>	43.82 $\pm$ 0.101 <sup>b</sup>	44.75 $\pm$ 0.139 <sup>c</sup>	45.40 $\pm$ 0.157 <sup>d</sup>
$S$	39.14 $\pm$ 0.826 <sup>d</sup>	37.68 $\pm$ 0.304 <sup>c</sup>	35.06 $\pm$ 0.181 <sup>b</sup>	33.91 $\pm$ 0.647 <sup>ab</sup>	33.35 $\pm$ 0.259 <sup>a</sup>
$\Delta E$	-	1.53 $\pm$ 0.923 <sup>a</sup>	3.53 $\pm$ 0.365 <sup>b</sup>	4.29 $\pm$ 0.198 <sup>bc</sup>	5.08 $\pm$ 0.419 <sup>c</sup>

<sup>a, b, c, d</sup> Means within the same row with different superscripts differ significantly ( $p < 0.05$ ); Emulsion-type chicken sausages: CON: without buckwheat flour; FB0: 3% of buckwheat flour at 0 months of storage; FB3: 3% of buckwheat flour at 3 months of storage; FB6: 3% of buckwheat flour at 6 months of storage; FB9: 3% of buckwheat flour at 9 months of storage

Compared to the CON product, significant differences were noted in the  $a^*$  and  $b^*$  values of FB sausages. By adding stored buckwheat grains (flour), the red and yellow tones of sausages are progressively reduced. These decreasing trends can be explained by the loss

of phenolic compounds as natural pigments, which is even more pronounced during thermally assisted long-term storage and drying (Kilincceker and Karahan, 2020; Pisinov et al., 2024). Our results were in agreement with the findings of Kilincceker and Karahan (2020), who found that added buckwheat flour caused a decrease in redness and yellowness of fried chicken meatballs.

Significantly lower  $C^*$  values were found in FB3, FB6 and FB9 sausages. The long-term stored buckwheat flour included in the formulation resulted in FB9 sausages had lower chromatic purity, showing the shortest distance from lightness compared to other sausages. For *hue* angle ( $h$ ) values between CON and FB0 did not differ significantly, but the significance increased with FB3, FB6 and FB9. The addition of buckwheat grains (flour) stored for 0 to 9 months led to a progressive increase in the proportion of yellow nuance in sausages. Cavalheiro et al. (2013) stated that  $C^*$  and  $h$  values depend on  $a^*$  and  $b^*$  values, and changes in these values are caused by the same reasons as those in  $a^*$  and  $b^*$ . The progressive loss of phenolic compounds is more pronounced as the storage time of buckwheat increases from 0 to 9 months, leading to a less saturated appearance of sausages, as the  $a^*$  and  $b^*$  values decrease and cause changes from red to yellow colour due to a more pronounced decrease in  $a^*$  than in  $b^*$  values. Varga-Visi et al. (2021) came to the same conclusion by examining sausage with paprika, where the changes in colour were attributed to the deterioration of the chromophores in meat and paprika, i.e. the decomposition of those pigments.

The  $S$  values of all emulsion-type chicken sausages differ significantly compared to CON. By adding long-term stored flour to the formulation, a decreasing trend of saturation was observed, which became more pronounced with longer storage. As the  $S$  value is derived from the  $L^*$  and  $C^*$  values, their reduction by incorporating long-term stored flour into the formulation directly causes a trend of decreasing  $S$  values from CON to FB9, for the same reasons as for  $L^*$  and  $C^*$ .

Furthermore, the total colour difference ( $\Delta E$ ) values gradually increased with the addition of longer-stored flour to the formulation. Variations in the  $L^*$ ,  $a^*$  and  $b^*$  parameters of sausages made from differently stored flour affected the total colour difference parameter ( $\Delta E$ ). This means that, compared to CON, the highest degree of colour change was observed for FB9. It is known that  $\Delta E$  values  $< 2.0$  indicate a colour difference compared to the control that the human eye cannot detect. In contrast to our results, Pietrzak et al. (2022) reported that there was no significant difference in  $\Delta E$  values when testing the effect of buckwheat hull extracts on the quality of chicken meatballs.

## CONCLUSION

The obtained results indicate that it is possible to use long-term stored buckwheat grains (flour) for up to 9 months without significantly impairing the visual properties of the final product. Colorimetric analysis of  $L^*$ ,  $a^*$ ,  $b^*$ ,  $C^*$ ,  $h$ ,  $S$  and  $\Delta E$  indicates that colour changes remain within the range sensory acceptable to consumers, and the optimal proportion of buckwheat flour in the formulation of products such as vacuum-packed emulsion-type chicken sausages is 3%. In this way, the meat industry is provided with reliable guidelines for the rational use of plant-based functional raw materials such as buckwheat in the development of products with improved colour-sensory properties.

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