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INFLUENCE OF STORED BUCKWHEAT ON COLOUR PARAMETERS OF EMULSION-TYPE CHICKEN SAUSAGES

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Abstract: The standard emulsion-type chicken sausage formulation was modified by incorporating buckwheat flour stored 0, 3, 6 and 9 months to obtain an enriched product and monitor the effect of instrumental colour change. The control (CON) and four combined frankfurter-buckwheat products with time-determined stored flour (FB0, FB3, FB6, and FB9) were analysed for instrumental colour properties (L*, a*, b*, *C**, *h*, *S*, ΔE). The results were statistically processed by one-way ANOVA ($P<0.05$) and Tukey's HSD post-hoc tests ($P<0.05$). Added buckwheat flour slightly affects L*, and significantly a* and b*, with the highest values in FB0 (similar to CON), which was lighter, redder and yellower than the other combined products. The *C** value significantly decreased ($P<0.05$), while the *h* value significantly increased ($P<0.05$) which caused lower chromatic purity and a more yellow nuance in FB9 (20.65, 45.40). Significant decrease in the *S* value resulted in the greatest attenuation in overall colour perception at FB6, and FB9. An increase trend of ΔE was observed, indicating the differentiation of sausages with respect to effect on total colour ($\Delta E \leq 5.08$). The results suggest that emulsion-type chicken sausages enriched with stored buckwheat flour are technologically justified and colour-sensory acceptable as end-products for consumers.

Key words: instrumental colour, buckwheat, chicken sausage, enriched product

Introduction

In recent years, with a focus on nutritionally justifiable and health-beneficial food, the attention has been directed to functional foods enriched with proven bioactive ingredients. In the modern meat industry, the addition of plant-based raw materials (grains, flour, husks, powder, extracts) into meat product formulations can effectively enhance various chemical, nutritional, functional, technological, and sensory properties (Safar et al., 2022; Yessengaziyeva et al., 2023). For these reasons, the development of recipes led to the production of composite products similar to frankfurter-type sausages, semi-smoked sausages, pork meatballs, horsemeat patties, chicken patties (Muchekeza et al., 2021; Salejda et al., 2022).

Buckwheat and its products are recognized for their health benefits due to high nutritional and functional value (Salejda et al., 2022; Coţovanu et al., 2023). It is characterized by the high content of bioflavonoids and minerals (K, B, Fe, Cu, Cr, Zn, Co, Ni, Ca, Mg, P, Na), vitamins B and E, as well as dietary fiber, essential amino acids and polyunsaturated fatty acids (Lee et al., 1995; Baumgertel et al., 2003; Salejda et al., 2022). As a staple food in the human diet, buckwheat grains are often stored for a prolonged period due to strategic reasons.

On the other hand, emulsion-type meat products such as frankfurter, are very popular and consumed worldwide (Wagh et al., 2015). A typical frankfurter consists of 40% pork and 60% beef, although it can also be made from 100% pork, 100% beef, and 100% poultry meat, as well as a combination of these types of meat. Another important raw material is fat tissue, which, together with meat, has a significant impact on yield, texture and microstructure (Mittal, 2005). Non-meat ingredients such as water, salt, nitrites, sugars, ascorbates, and phosphates contribute to the quality, taste, and flavor, while spices, flavorings, and antioxidants significantly influence the flavor profile (Lonergan et al., 2019).

Generally, meat products are considered unhealthy due to their high lipid and cholesterol content. However, incorporating buckwheat and its products in well-known conventional meat products, among others, frankfurters, enables the development of functional meat foods with improved quality. Despite their favorable nutritional profile, buckwheat-enriched meat products may exhibit altered sensory characteristics that negatively influence consumer acceptance (Pietrzak et al., 2022). Therefore, less favourable sensory features, specifically colour, may reduce the quality attributes of overall acceptability for consumers. These colour changes can be even greater, i.e. enhanced, as green buckwheat flour is used in the production of emulsion-type sausages (e.g. frankfurter-type) that require thermal processing (Wagh et al., 2015; Atambayeva et al., 2023; Yessengaziyeva et al., 2023; Rakić et al., 2024). Some factors, such as oxidative reactions, the Maillard reaction, product drying, and the presence of antioxidants, are directly related to the colour change of frankfurters (Wagh et al., 2015).

The aim of this study was to evaluate the colorimetric (L*, a*, b*, *C**, *h*, *S*, and ΔE) characteristics and provide a technological reference for colour changes based on the incorporation of 0-, 3-, 6- and 9-months stored buckwheat flour in the formulation of emulsion-type chicken sausages to obtain technologically justified and colour-sensory acceptable combined end-products for consumers.

Materials and Methods

Plant material

The buckwheat variety used in this study was "*Novosadska*", which was harvested at the seed's technological maturity. Sampling was carried out according to ISO 24333 (2009), and a bulk of 2 kg sample was stored as previously reported Ping-Ping et al. (2019). Briefly, grains were equally distributed in eight samples, of which six were stored in plastic containers for 3, 6, and 9 months in a drying oven (Digitheat-TFT, J.P Selecta, Barcelona, Spain). The conditions were maintained at a temperature of 40 ± 2 °C with thermoregulation control and a relative humidity of 50%. At the end of each testing period, a subsample (approximately 0.5 kg) was formed from two samples, crushed and ground at a speed of 20000 rpm in an A10 laboratory mill (IKA Works Inc., NC, Wilmington, USA). A wholegrain buckwheat flour material was prepared in triplicate (particle size of 1 mm), and used for the preparation of emulsion-type chicken sausages.

Emulsion-type chicken sausage preparation

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 treatments of sausages were prepared, each in batches of 2 kg, with the formulations shown in Table 1, according to Lee et al. (2018), with some modifications. The production process was common for industrial production and identical for all treatments. All formulations contained equal amounts of ingredients, except for the addition of buckwheat flour. The control treatment (CON) was made of mechanically separated chicken meat (MSM) without adding buckwheat flour, while in other treatments, buckwheat flour stored for 0 (FB0), 3 (FB3), 6 (FB6), and 9 (FB9) months was separately added. After preparation, emulsion-type chicken sausages were vacuum-packed (with 99.9% of vacuum level) and stored at 2 ± 2 °C before analysis. Three replications of the experiment were conducted.

Table 1. Recipe formulation of emulsion-type chicken sausages (kg)

Composition (kg)/Group	CON	FB0	FB3	FB6	FB9
MSM	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

Note: **Ingredients:** 2.00% potato starch, 1.80% salt (with 0.5% $NaNO_2$), 0.85% seasoning, 0.80% beef protein, 0.30% stabilizer - complete, 0.10% carrageenan, and 0.01% colour (E120).

Determination of instrumental colour parameters

The instrumental colour was measured at five opposite points of the longitudinal section for each emulsion-type chicken sausage on chromameter CR-400 (Konica Minolta Sensing Inc., Osaka, Japan). Conditions were corresponded to diffuse light D-65 (average daylight which has a correlated colour temperature of approx. 6 500 K), a standard angle of 2 degrees of shelter and 8 mm aperture of the measuring head as described by Stajić et al. (2014).

The results were expressed in CIEL*a*b* system (CIE, 1976) 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 against a white standard (tile) (L* = +97.83, a* = –0.43, b* = +1.98).

*C** (chroma - percentage of black, white or gray; eq. 1) and *h* (hue angle; 0° - red colour, 90° - yellow colour; eq. 2) were calculated using the following equations:

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad \text{(eq. 1)}$$

$$h = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad \text{(eq. 2)}$$

S (perceived saturation; eq. 3) defined as the proportion of pure chromatic colour in the total colour sensation was calculated using the following equation:

$$S = \frac{C^*}{\sqrt{C^{*2} + L^{*2}}} 100\% \quad \text{(eq. 3)}$$

Total colour difference (ΔE; eq. 4) of treatments with incorporated buckwheat flour (stored for 0, 3, 6 and 9 months) relative to CON (without buckwheat flour) was calculated as follows (Pietrzak et al., 2022):

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad \text{(eq. 4)}$$

Statistical analysis

The instrumental colour parameters (mean (M) ± standard deviation (SD)) were analysed by one-factor analysis of variance (one-way ANOVA, $P<0.05$) to evaluate the effect of sausage formulation. Tukey's HSD (Honestly Significant Difference, $P<0.05$) post-hoc test was applied to identify significant differences between means. Statistical analyzes were 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 emulsion-type chicken sausages as a product type factor. Different formulations of the same sausage product had a statistically significant influence on all instrumental colour parameters ($P<0.05$). Moreover, progressive changes were noted with increasing storage time of buckwheat flour, in all observed instrumental colour parameters.

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

n=3 (five points each)	Product type				
Parameters	CON	FB0	FB3	FB6	FB9
L*	$59.25±0.499^{ab}$	$60.65±0.467^{b}$	$58.70±0.091^{a}$	$58.95±0.523^{a}$	$58.39±0.876^{a}$
a*	$19.07±0.316^{c}$	$18.57±0.190^{c}$	$15.86±0.092^{b}$	$15.09±0.361^{a}$	$14.50±0.170^{a}$
b*	$16.48±0.454^{b}$	$16.25±0.212^{b}$	$15.22±0.127^{a}$	$14.96±0.285^{a}$	$14.71±0.112^{a}$
*C**	$25.21±0.537^{c}$	$24.67±0.275^{c}$	$21.98±0.147^{b}$	$21.25±0.456^{ab}$	$20.65±0.193^{a}$
h	$40.83±0.307^{a}$	$41.18±0.159^{a}$	$43.82±0.101^{b}$	$44.75±0.139^{c}$	$45.40±0.157^{d}$
S	$39.14±0.826^{d}$	$37.68±0.304^{c}$	$35.06±0.181^{b}$	$33.91±0.647^{ab}$	$33.35±0.259^{a}$
ΔE	-	$1.53±0.923^{a}$	$3.53±0.365^{b}$	$4.29±0.198^{bc}$	$5.08±0.419^{c}$

$^{a, b, c, d}$ 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, the storage period of buckwheat incorporated into the products did not affect the L* values ($P>0.05$). However, emulsion-type chicken sausage with 0 months stored buckwheat flour (FB0) was significantly lighter in comparison to other composite products. This difference in lightness (darkening) was associated with buckwheat grains (flour) stored for 3-, 6- and 9-months as development of lipid oxidation and the Maillard reaction products readily occurs during thermally assisted long-term storage and drying (Jambrec et al., 2011; Pietrzak et al., 2022; Pisinov et al., 2024). Generally, the findings of Lee et al. (2018) and Kilincceker and Karahan (2020) were in agreement with our results (although FB0 to CON is not significant), as they found that added buckwheat flour to emulsion-type pork sausages (3%) or chicken meatballs caused an increase in L* values. Later disagreements with our results (darker FB3, FB6, FB9 *cf.* CON) came from the fact that their research was performed with only one, non-stored type of buckwheat flour.

In relation to the CON product, significant differences in a* and b* values were observed in FB3, as well as in FB6 and FB9. By adding buckwheat grains (flour) stored for a longer period, 3-9 months, red and yellow tones of emulsion-type chicken sausages progressively decreased (from 15.86 to 14.50, and from 15.22 to 14.71, respectively). These decreasing trends could 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). Regarding a* and b* values, 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. Similarly, Lee et al. (2018) reported that adding 3% of buckwheat powder in emulsion-type pork sausage resulted in a lower a* value, which was in accordance with our results, especially for FB3, FB6, and FB9. However, there is disagreement about the b* value, which could be explained by the source, form, and amount of flour added to the product.

The significantly lower *C** values ($P<0.05$) compared to CON, were found in emulsion-type chicken sausage with incorporated 3-month stored buckwheat flour (FB3) and more long-term stored buckwheat flour (FB6 and FB9). Increasing the storage time of buckwheat flour included in the formulation resulted in FB9 sausages having lower chromatic purity, showing the smallest distance from lightness compared to other sausages. Similar to chroma (*C**), hue angle (*h*) values between CON and FB0 did not differ significantly, but the significance increased with FB3, as well as in FB6 and FB9. The addition of buckwheat grains (flour) stored from 0- to 9-months, led to a significant progressive increase in the proportion of yellow nuance in emulsion-type chicken sausage, with the largest change in value at FB9. 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*. Therefore, the progressive loss of phenolic compounds was more pronounced as storage time of buckwheat flour increases from 0- to 9-months, which led to less saturated sausage products because a* and b* decreased, and caused changes from red to yellow as the decrease of a* was more emphasized than that of b*. 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 were significantly different ($P<0.05$) for all emulsion-type chicken sausages compared to CON, which had the highest value. By adding long-term stored buckwheat flour into the formulation, a decreasing trend of saturation was observed, which became more pronounced with longer buckwheat storage. Our results showed that the proportion of pure chromatic colour in overall colour sensation was significantly reduced from CON to FB9. Since the *S* value is derived from L* and *C** values, their reduction by incorporating long-stored buckwheat flour into the formulation directly causes a decreasing trend in *S* value from CON to FB9, for the same reasons as those for L* and *C**.

Further, total colour difference (ΔE) values gradually increased with the addition of longer-stored buckwheat flour to the formulation. The lowest ΔE value was observed for FB0, and the highest for FB9, while there was no significant difference between FB3 and FB6 values ($P>0.05$). Variation in L*, a* and b* colour parameters of emulsion-type chicken sausages made with differently stored buckwheat flour affected the total colour difference parameter (ΔE). This means that compared to CON, the highest degree of colour change was observed for FB9, i.e. emulsion-type chicken sausage whose formulation contains buckwheat flour stored for 9 months. It is known that $\Delta E<2.0$ values indicate a colour difference compared to the control that cannot be detected by the human eye (Pietrzak et al., 2022). Wójtowicz et al. (2013) investigated colour parameters of extruded corn snacks enriched with buckwheat flour up to 50%, and found colour differences between treatments similar to our study. In contrast to our results, Pietrzak et al. (2022) reported that there was no significant difference in ΔE values when testing the effect of buckwheat hull extracts on the quality of chicken meatballs.

Conclusion

The results indicated the potential utilization of long-term stored buckwheat grains (flour) as a functional ingredient and valuable plant-based raw material in the production of enriched, combined products such as vacuum-packed emulsion-type chicken sausages. The addition of 3% buckwheat flour stored for 0-, 3-, 6- and 9-months in the formulation of emulsion-type chicken sausages slightly decreased lightness (L*), but significantly lowered a* and b* values. Furthermore, instrumental colour analysis showed significantly decreased *C** and *S* values, while the *h* value progressively increased. Also, the addition of stored buckwheat flour resulted in differentiation of sausages in terms of the impact on total colour ($\Delta E \leq 5.08$). The degree of correlation between instrumental colour values and combined products depends on all factors governing lipid oxidation, the Maillard reaction and levels of phenolic compounds. Considering that the instrumental colour represents only a part of the more complex methodology of the product sensory evaluation, it is necessary to conduct more extensive researches of sensory attributes (taste, odour...), textural profile, and the technological properties of the buckwheat-enriched meat emulsion stability. Since colour changes mainly influence purchasing decisions, emulsion-type chicken sausages enriched with stored buckwheat flour proved to be technologically viable and colour-sensory acceptable end-products for consumers.

Uticaj skladištene heljde na parametre boje pilećih kobasica tipa emulzije

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Rezime

Standardna formulacija pileće kobasice emulzionog tipa je modifikovana dodavanjem heljdinog brašna skladištenog 0, 3, 6 i 9 meseci kako bi se dobio obogaćen proizvod i pratio efekat promene instrumentalne boje. Kontrola (CON) i četiri kombinovana frankfurter-heljda proizvoda sa brašnom skladištenim na određeni vremenski period (FB0, FB3, FB6 i FB9) su analizirani na svojstva instrumentalne boje (L*, a*, b*, *C**, *h*, *S*, ΔE). Rezultati su statistički obrađeni testovima jednofaktorska ANOVA ($P<0.05$) i Tukey-jev HSD post-hoc ($P<0.05$). Dodato heljdino brašno neznatno utiče na L*, a značajno na a* i b*, sa najvišim vrednostima u FB0 (sličan CON), koji je bio svetliji, crveniji i žući od ostalih kombinovanih proizvoda. Vrednost *C** se značajno smanjila ($P<0.05$), dok se vrednost *h* značajno povećala ($P<0.05$) što je uzrokovalo nižu hromatsku čistoću i više žute nijanse kod FB9 (20.65, 45.40). Značajno smanjenje *S* vrednosti rezultiralo je najvećim slabljenjem u ukupnoj percepciji boje kod FB6 i FB9. Primećen je trend povećanja ΔE, što ukazuje na diferencijaciju kobasica u pogledu uticaja na ukupnu boju ($\Delta E \leq 5{,}08$). Rezultati ukazuju da su pileće kobasice emulzionog tipa obogaćene skladištenim heljdinim brašnom tehnološki opravdane i po boji senzorno prihvatljive kao gotovi proizvodi za potrošače.

Ključne reči: instrumentalna boja, heljda, pileća kobasica, obogaćeni proizvod

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Conflict of interest
The authors declare no conflict of interest.

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