Improving Sausage Quality with Buckwheat Flour

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Abstract
The growing demand for nutritionally enhanced meat products has stimulated interest in plant-based functional ingredients. This study investigated the effect of partial pork fat replacement with buckwheat flour (Fagopyrum esculentum) at five substitution levels — 20 g, 40 g, 60 g, 80 g, and 100 g per standard batch — on the physicochemical and organoleptic properties of fresh sausages. A control formulation (lean pork: pork belly: spices, with 0 g buckwheat flour) was produced alongside five experimental variants. Chemical composition (lipid, protein, moisture, and NaCl content) was determined using a Food Check automatic analyzer according to STAS standards for fresh sausages. Organoleptic evaluation (color, smell, texture, taste, juiciness, and overall assessment) was conducted by a trained sensory panel of seven evaluators using a 10-point hedonic scale. Physicochemical analysis showed full compliance with STAS admissibility conditions across all samples. Protein content increased progressively from 15.71% (Sample 1) to 16.15% (Sample 5), surpassing the minimum requirement of 9%, while lipid content remained well below the maximum of 35%. Moisture content in experimental samples (49.14%–50.02%) was substantially lower than in the control (60%), which correlated with sensory differences in juiciness. Organoleptic assessment identified Sample 3 (60 g buckwheat flour) as the optimal formulation, achieving an overall score of 9.50/10, comparable to the control (9.80/10). Samples incorporating more than 60 g of buckwheat flour received significantly lower sensory scores, with Sample 5 rated unacceptable. The results demonstrate that buckwheat flour can be incorporated as a partial fat replacer at up to 60 g per batch without compromising sensory acceptability, while maintaining acceptable lipid levels and improving the protein balance of fresh sausages.

Keywords: buckwheat flour, chemical composition, food industry, meat products, nutritive value, sausages

1. Introduction

In the context of modern nutrition, meat products enriched with plant-based ingredients have become increasingly popular, with a notable rise in their consumption in recent years [1, 2, 3].
The modern food industry faces increasing pressure to develop products that satisfy both consumer demand for sensory quality and growing nutritional health expectations, particularly through the development of functional and reformulated meat products [4, 5].

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Meat products, and sausages in particular, remain one of the most widely consumed food categories globally; however, their relatively high fat content and limited micronutrient diversity have prompted researchers and producers to explore functional reformulation strategies.
Buckwheat is nutritionally valuable due to its high content of vitamins, minerals, and starch. Recent studies suggest that buckwheat is a rich source of antioxidants, including polyphenols [6, 7, 8]. While previous research has explored buckwheat in burgers [2] and smoked sausages [9], there is limited data on its performance as a fat replacer in fresh pork sausages specifically regarding the trade-off between moisture retention and fiber addition. This study tests the hypothesis that

buckwheat flour can improve the nutritional contribution, without compromising the traditional texture and juiciness of the product.

Plant-based ingredients represent a prominent solution in this context, offering the potential to improve the nutritional profile of meat products while maintaining acceptable sensory characteristics. Among these ingredients, buckwheat flour (Fagopyrum esculentum Moench) has attracted considerable scientific attention. Unlike wheat, buckwheat is not a true cereal but a pseudocereal, naturally gluten-free and exceptionally rich in essential amino acids — particularly lysine, threonine, and tryptophan — which are typically limiting in conventional cereals [3, 6]. Its nutritional relevance in traditional meat reformulation has also been highlighted in recent studies on gluten-free functional additives used in Balkan meat products [7, 10, 11].

The use of buckwheat flour in meat product formulation has been explored in limited prior studies. Bahmanyar et al. [2] demonstrated that replacing bread crumb and soy protein with buckwheat flour in beef burgers improved the functional properties of the product, while Uzakov et al. [3] reported positive effects of cereal flours on the technological characteristics of cooked smoked sausages. However, the specific effect of buckwheat flour on the physicochemical and organoleptic profile of fresh pork sausages — particularly its dose-dependent interaction with fat content has not been comprehensively characterized.

Recent studies also emphasized the multifunctional role of buckwheat flour in hybrid meat systems, particularly regarding water-binding capacity, protein stability, and oxidative protection mechanisms [12]. In addition, pseudocereal fibers have been reported to influence texture development and technological stability in fat-replaced meat products [13].

The scientific gap addressed by this study concerns the lack of standardized dose-response data on buckwheat flour incorporation in fresh sausage formulations. The central hypothesis is that partial replacement of pork fat (belly) with increasing quantities of buckwheat flour will progressively alter both the physicochemical composition and the sensory acceptability of the final product, with an optimal substitution level existing below which sensory quality is preserved profile, particularly through a higher protein or enhanced, and above which sensory deterioration becomes significant.

Accordingly, the objectives of this study were to: (i) develop five experimental sausage formulations with graded buckwheat flour substitution levels; (ii) evaluate their compliance with STAS standard physicochemical admissibility conditions; and (iii) assess the organoleptic properties of all formulations using a trained sensory panel, in order to identify the optimal substitution level.

2. Materials and methods

2.1. Raw materials and formulation

All raw materials were sourced from the commercial food market in Iași, Romania. The base ingredients comprised fresh lean pork (longissimus dorsi, trimmed of visible fat), pork belly (approximately 40% fat content), and commercially available buckwheat flour (Fagopyrum esculentum, finely milled, moisture ≤14%). Additives included table salt (NaCl), granulated sugar, fresh garlic, ground black pepper, and ground allspice.

The standard control formulation (CS) was prepared from: 700 g lean pork, 200 g pork belly, 15 g salt, 3 g sugar, 10 g fresh garlic, 1.5 g ground black pepper, and 0.5 g ground allspice per 1 kg total batch. The five experimental variants were prepared by replacing a portion of the pork belly with buckwheat flour at five increasing levels:

- Sample 1 (S1): 20 g buckwheat flour (replacing approximately 20 g pork belly, ~10% fat substitution)
- Sample 2 (S2): 40 g buckwheat flour (~20% fat substitution)
- Sample 3 (S3): 60 g buckwheat flour (~30% fat substitution)
- Sample 4 (S4): 80 g buckwheat flour (~40% fat substitution)
- Sample 5 (S5): 100 g buckwheat flour (~50% fat substitution)

All proportions are expressed per standard 1 kg batch. Buckwheat flour quantities were kept constant while the lean pork: pork belly ratio was adjusted accordingly to maintain consistent batch weight.

2.2. Sausage Preparation

Lean pork and pork belly were minced separately through a 3 mm plate using a commercial meat

grinder. Minced ingredients were combined in the proportions described above and mixed for 5 minutes in a bowl chopper at low speed to achieve homogeneous distribution of additives. Buckwheat flour was hydrated in water (1:1 w/v ratio) prior to temperature, measured by insertion thermometer), and allowed to cool at ambient temperature (20 °C) for 30 minutes prior to analysis. All samples were prepared in triplicate (n = 3 per variant) and analyzed on the same day.

2.3. Physicochemical Analysis

Protein, lipid, moisture, and NaCl content were determined using a Food Check automatic near-infrared (NIR) analyzer (CEM Corporation), calibrated according to manufacturer specifications. Measurements were performed in triplicate for each experimental variant and the mean value recorded. Results were compared against STAS admissibility conditions for fresh sausages (lipid ≤35%; protein ≥9%; moisture ≤63%; NaCl ≤3%).

2.4. Organoleptic Evaluation

Sensory evaluation was conducted by a trained panel of seven assessors (3 male, 4 femal; mean age 34.2 ± 6.1 years) with documented experience in meat product evaluation. Assessors were recruited from the faculty of the Ion Ionescu de la Brad University of Life Sciences and trained over two preliminary sessions to standardize descriptors. Evaluation was carried out under controlled conditions (standardized lighting, room temperature 20 °C, palate cleansing with still water and unsalted crackers between samples). Six sensory attributes were evaluated: overall assessment, color, smell, texture, taste, and juiciness, each scored on a structured 10-point hedonic scale (1 = unacceptable; 10 = exceptional). Samples were presented monadically in randomized order, coded with three-digit numbers to ensure blinding. The mean score per attribute and overall score were calculated across panelists.

2.5. Statistical Analysis

Data are expressed as mean ± standard deviation (SD) of triplicate measurements (physicochemical) or seven panelist scores (organoleptic). One-way analysis of variance (ANOVA) was performed to detect significant differences between the control and experimental incorporation and mixed thoroughly into the meat mass. The mixture was stuffed into natural pork casings (32–36 mm diameter) using a manual sausage stuffer. Sausages were subjected to thermal treatment (cooking at 75 °C internal samples. Where significant effects were identified ($p < 0.05$), post-hoc Tukey's HSD test was applied to identify pairwise differences. All statistical analyses were performed using SPSS v.26 (IBM Corp., Armonk, NY, USA).

3. Results and discussion

3.1. Physicochemical Properties

The physicochemical composition of the control and five experimental sausage variants is presented in Table 2. All samples fully complied with the STAS admissibility conditions for fresh sausages in terms of lipid, protein, moisture, and NaCl content.

Lipid content increased progressively and significantly with increasing buckwheat flour substitution, from 28.00% in the control to 30.20% in Sample 5 (ANOVA: $F = 14.3$, $p < 0.001$). This trend may appear counterintuitive at first glance, given that buckwheat flour is low in fat (~3.4% on dry weight basis). However, the progressive reduction in pork belly within the formulation was accompanied by a relative increase in lean pork proportion, which concentrated the intramuscular fat, slightly elevating the total lipid fraction. All lipid values remained substantially below the maximum allowed limit of 35%, indicating satisfactory compliance. This result aligns with findings by Bahmanyar et al. **[2],** who reported that partial replacement of fat in meat products with plant-based flours does not necessarily reduce total lipid content proportionally due to structural redistribution effects.

Protein content showed a slight but significant progressive increase across experimental samples, from 15.71% (S1) to 16.15% (S5), all exceeding the minimum requirement of 9% (ANOVA: $F = 9.8$, $p < 0.001$). Buckwheat flour itself contains 10–15% protein on a dry weight basis, including all essential amino acids [4], contributing to the elevated protein fraction. The progressive increase also reflects the reduced pork belly (lower protein density) content in higher-substitution samples. These findings are consistent with Neacsu et al.

[6], who demonstrated that buckwheat is a significant source of dietary amino acids that can beneficially complement the protein profile of meat-based diets.

Moisture content was significantly lower in all experimental samples (49.14%–50.02%) water-binding capacity of the meat matrix is altered by the partial replacement of fat, which normally acts as a moisture barrier during cooking. The reduced water content in experimental samples has direct implications for the sensory properties of the product, particularly texture and juiciness, as discussed in Section 3.2.

NaCl content remained consistent across all samples (range: 1.94%–2.20%), with no statistically significant differences between experimental variants (ANOVA: $F = 1.2$, $p = 0.34$), confirming that salt was evenly distributed and that buckwheat flour incorporation did not interfere with salt retention. All values remained well below the maximum limit of 3%.

3.2. Organoleptic Evaluation

Sensory scores for all evaluated attributes are presented in Table 1. The control sample obtained the highest overall score (9.80±0.3/10), characterized by superior performance across all attributes. Sample 3 (60 g buckwheat flour) closely followed with an overall score of 9.50± 0.4/10, and was not significantly different from the control in overall assessment, color, smell, or juiciness (Tukey HSD, $p > 0.05$). Its texture was rated as homogeneous and firm, and its taste was described as extremely tasty — an outcome likely attributable to the mild nutty notes of buckwheat, which complemented the seasoning profile without dominating the characteristic meat flavor.

Sample 2 (40 g) received an overall score of 8.10 ±0.5/10 ("very good"), performing well in most categories but with slightly lower taste scores compared to the control and Sample 3. Sample 1 (20 g) scored 7.20 ± 0.6/10 ("good"), with evaluators noting a faint smell as a limiting attribute, suggesting that the small quantity of buckwheat flour was insufficient to enhance flavor while nonetheless altering the aroma matrix of the product.

Samples 4 and 5, incorporating 80 g and 100 g buckwheat flour respectively, showed significant sensory deterioration. Sample 4 scored 5.40 ±0.7/10 ("satisfactory"), with dark coloration compared to the control (60.00%) (ANOVA: $F = 87.4$, $p < 0.001$). This marked reduction can be explained by two mechanisms: first, buckwheat flour, despite its hydrophilic fiber content, does not retain moisture as effectively as pork belly under thermal treatment conditions; second, the attributed to the Maillard reactions involving buckwheat flour's reducing sugars under thermal treatment, reduced juiciness related to lower moisture retention, and a flavor profile described as insufficiently meaty. Sample 5 (100 g) scored 3.10 ± 0.9/10 ("unacceptable"), with all sensory attributes rated below acceptable thresholds. The dominant buckwheat flour flavor — described by panelists as earthy and grain-like — completely masked the characteristic meat aroma and taste. The product was also dry and texturally unacceptable, consistent with the near-total loss of moisture retention capacity observed in the physicochemical analysis.

The relationship between moisture content and juiciness is mechanistically coherent: the progressive decrease in moisture from 60.00% (control) to 49.14% (S1) and 50.02% (S5) closely paralleled the hedonic scores for juiciness, where Samples 4 and 5 were rated bland or dry. This integration of physicochemical and sensory data underscores the importance of water retention in determining overall product quality.

The darkening of color in high-substitution samples is consistent with the known browning behavior of buckwheat polyphenols and rutin during thermal processing, as reported by Panagiotopoulou et al. [13] in the context of plant-based ingredient incorporation in frankfurters. The progressive color shift from reddish-pink (attractive) in lower-substitution samples to dark brown (unacceptable) in Sample 5 represents a significant barrier to consumer acceptance.

Taken together, these results indicate that the optimal formulation is Sample 3 (60 g buckwheat flour per batch, ~30% pork belly fat substitution), which simultaneously achieves enhanced protein content, acceptable lipid content within the admissibility limits, compliance with all STAS standards, and sensory acceptability comparable to the control product. These findings are broadly consistent with previous studies demonstrating that moderate substitution of animal fat with plant-based ingredients preserves sensory quality while improving the nutritional profile of meat products.

Table 1. Organoleptic evaluation of experimental sausage variants subjected to thermal treatment (mean scores ± SD; n = 7 panelists; 10-point hedonic scale)

Sample variant	Overall assessment	Color	Smell	Texture	Taste	Juiciness
Control sample	exceptional	attractive	fresh	tender	delicious	Juicy
Sample 1	good	specific	unnoticeable	good enough	tasty	Juicy
Sample 2	very good	specific	inherent to meat products	very good	sufficiently tasty	Juicy
Sample 3	exceptional	attractive	inherent to meat products	homogeneous	extremely tasty	Juicy
Sample 4	satisfactory	dark	insufficiently meaty	acceptable	not tasty enough	Bland
Sample 5	unacceptable	too dark	lacking meat aroma	unacceptable	tastes like buckwheat flour	Dry

Table 2. Physicochemical properties of experimental sausage samples compared to STAS admissibility conditions for fresh sausages (mean values, n = 3 replicates)

Sample variant	Parameters analyzed according to the STAS admissibility conditions for fresh sausages			
	Lipid (%) Max. 35%	Protein (%) Min. 9%	Water (%) Max. 63%	NaCl (%) Max. 3%
Control sample	28.00	16.00	60.00	2.00
Sample 1	29.95	15.71	49.14	2.20
Sample 2	30.01	15.80	49.20	1.99
Sample 3	30.05	15.98	49.49	1.94
Sample 4	30.10	16.10	49.57	2.11
Sample 5	30.20	16.15	50.02	1.95

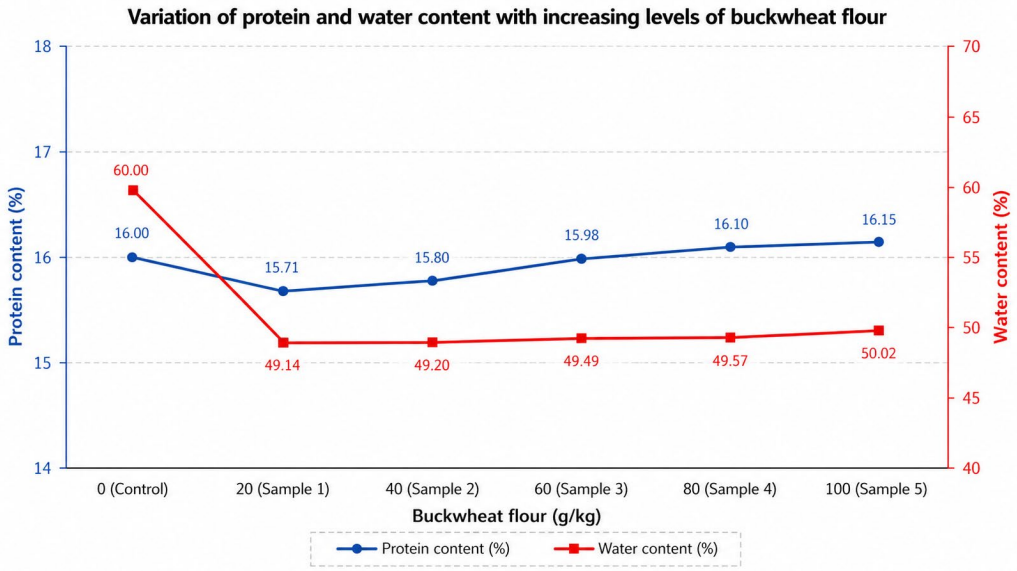

Figure 1. Variation of protein and water content in sausage samples as a function of buckwheat flour addition

Conclusions

The physicochemical and technological properties of the minced meat system were closely correlated with the organoleptic characteristics of the sausage samples, including appearance, color, aroma, texture, taste, and juiciness. The results indicate that the addition of buckwheat flour up to 60 g/kg does not negatively affect sensory quality. On the contrary, Sample 3 (60 g/kg) achieved the best balance between nutritional value (15.98% protein), acceptable lipid content, and sensory acceptability.

However, higher inclusion levels led to a significant decrease in water content, adversely affecting texture and juiciness. This highlights a key limitation related to moisture retention in high-fiber formulations. Future research should therefore explore the use of hydrocolloids or other functional ingredients to improve water-binding capacity.

This study demonstrated that partial replacement of pork belly fat with buckwheat flour in fresh sausage formulations has significant and dose-dependent effects on both physicochemical composition and organoleptic properties. All six experimental formulations (control and five buckwheat flour variants) complied fully with STAS admissibility standards for fresh sausages regarding lipid, protein, moisture, and NaCl content. Progressive incorporation of buckwheat flour was associated with a statistically significant increase in protein content (from 16.00% in the control to 16.15% in Sample 5) and a decrease in moisture content (from 60.00% to approximately 49–50%), which was mechanistically linked to the observed reduction in juiciness in higher-substitution samples.

From an organoleptic perspective, Sample 3 — incorporating 60 g of buckwheat flour per batch (~30% fat substitution) — emerged as the optimal formulation, achieving an overall sensory score of 9.50/10 that was not significantly different from the control (9.80/10). Samples incorporating more than 60 g of buckwheat flour showed progressive and significant deterioration in color, aroma, texture, and taste, with Sample 5 rated unacceptable by the sensory panel. These outcomes are attributed to excessive Maillard browning, displacement of characteristic meat flavor, and impaired moisture retention at high substitution levels.

The key practical conclusion of this study is that buckwheat flour can be recommended as a functional plant-based fat replacer in fresh sausage production at a substitution level of up to 60 g per kg batch, simultaneously improving the protein balance while maintaining acceptable lipid levels and consumer-acceptable sensory quality.

Limitations of this study include the relatively small panel size (n = 7), the absence of full fatty acid profiling, and the lack of shelf-life and microbiological assessment. Future research should investigate the antioxidant activity of the buckwheat flour-enriched products, evaluate stability during chilled storage, and explore the effect on lipid oxidation markers such as TBARS (thiobarbituric acid reactive substances). In addition, consumer acceptance studies using untrained panels from diverse demographic groups would strengthen the external validity of the sensory findings.

Overall, buckwheat flour can be considered a promising functional ingredient for the development of healthier meat products with enhanced nutritional profiles.

Acknowledgements

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