Vegetable Flour Fortification of Chicken Liver Nuggets: Enhancing Nutritional and Structural Quality

Dedes Amertaningtyas[a]*, Feri Eko Hermanto[b], Muhamad Hanif Rawi[c] & Ahmad Khoirul Umam[a]

[a]Department of Animal Product Technology, Faculty of Animal Science, Brawijaya University, East Java, 65145 Indonesia
[b]Department of Intelligence Livestock Industry, Faculty of Animal Science, Brawijaya University, East Java, 65145 Indonesia
[c]Food Security Research Laboratory, Faculty of Food Science and Nutrition, University Malaysia Sabah, Sabah, 88400 Malaysia

Abstract

The growing demand for functional foods has encouraged the utilization of chicken liver, a rich source of protein and micronutrients. This study developed chicken liver nuggets fortified with vegetable-based flours—cornstarch, soybean, pumpkin, and carrot—at a 5% inclusion level to enhance value and mitigate sensory limitations. A randomized block design was employed to evaluate key parameters, including iron, vitamin A, cholesterol, antioxidant activity (IC_{50}), microstructure, and sensory acceptance. Results indicated significant improvements (p<0.01) compared to the control formulation (tapioca-only). Soybean flour increased iron content to 29.45±1.14 ppm; carrot flour elevated vitamin A to 1015.62±7.55 µg/100g and reduced cholesterol to 148.64±1.36 mg/100g; and pumpkin flour exhibited the strongest antioxidant activity (IC_{50}: 162.23±3.33 mg/mL). Scanning electron microscopy (SEM) revealed that cornstarch produced compact structures, whereas soybean and carrot flours resulted in more porous matrices. Sensory evaluation demonstrated that nuggets containing cornstarch received the highest scores for taste, texture, and overall impression, indicating improved consumer acceptability through flavor masking and enhanced mouthfeel. In contrast, pumpkin and carrot flours adversely affected aroma and texture, while soybean flour received moderate acceptance. These findings confirm that vegetable-based flours can substantially improve both the nutritional and sensory attributes of chicken liver nuggets, offering a sustainable approach to developing healthier meat-based products.

Keywords: Carrot, Cornstarch, Fortification, Pumpkin, Soybean

***Corresponding Author**
e-mail: dedesfptub@ub.ac.id

Introduction

Global food security and nutritional deficiencies necessitate innovative strategies to develop nutrient-dense functional foods. Animal by-products, such as chicken liver, rich in protein, iron, and vitamin A (Malichati & Adi, 2018), represent underutilized resources with the potential to address these challenges. However, its strong flavor, soft texture, and high cholesterol content limit consumer acceptance (Jaya & Yusanti, 2018; Thohari et al., 2017). Addressing this dichotomy requires advanced processing techniques to transform chicken liver into palatable, nutrient-enhanced products such as nuggets.

Recent studies highlight the role of vegetable-based ingredients in improving the physicochemical and sensory properties of meat products. Soybean, pumpkin, and carrot flours enhance texture, stabilize structure, and contribute bioactive compounds and dietary fiber (Amertaningtyas et al., 2021). Cornstarch improves iron bioavailability, while pumpkin and carrot flours elevate vitamin A content and antioxidant capacity (Marbun et al., 2018; Urip et al., 2021). Additionally, plant-based ingredients modulate lipid metabolism, thereby reducing cholesterol levels (Ajibola et al., 2015). These findings position vegetable flours as viable solutions for improving nutritional quality and masking undesirable sensory traits in animal by-products.

Advances in fat substitutes and fiber incorporation further support this approach. Alternative fats have been shown to enhance the sensory and nutritional attributes of beef burgers formulated with oat flour, apple peel flour, green banana pulp, and green banana peel (Talukder, 2015; Talukder et al., 2015). Plant-derived oils also improve lipid stability in meat systems (Botella-Martínez et al., 2021), reinforcing the rationale for vegetable-based formulations. Innovations like canned meat-vegetable blends (Chuyev et al., 2021) and fat-reduced frankfurters incorporating banana by-products (Pereira et al., 2020) exemplify the success of hybrid animal-plant formulations. However, structural and textural evaluations remain critical for optimizing such products (Samard & Ryu, 2019).

This study investigated the incorporation of cornstarch, soybean, pumpkin, and carrot flours into chicken liver nuggets to simultaneously address sensory limitations and enhance nutritional profiles. Using a randomized block design, it evaluates the effects of each flour on antioxidant capacity, iron content, cholesterol reduction, vitamin A levels, and microstructural integrity. Building on recent advancements in functional meat pâtés (Borsolyuk & Verbytskyi, 2023), this approach aligns with sustainable food production trends. For example, fungi–vegetable blends (Muliani et al., 2021) and omega-3–enriched feeds (Kartikasari et al., 2023) highlight the dual benefits of nutritional enhancement and environmental sustainability. However, gaps persist in optimizing unconventional ingredients for meat systems (Soji-Mbongo & Mpendulo, 2024).

Despite progress in hybrid meat–plant formulations, few studies systematically analyze the synergistic effects of vegetable flours on both sensory and nutritional parameters in underutilized animal by-products such as chicken liver. Existing research often focuses on singular vegetable additives or conventional meats, overlooking the unique physicochemical challenges posed by liver-based matrices. Furthermore, mechanistic insights into how vegetable flours influence cholesterol content, micronutrient retention, and microstructure remain underexplored. Therefore, this study aims to bridge these gaps by evaluating the comparative efficacy of cornstarch, soybean, pumpkin, and carrot flours in enhancing the antioxidant capacity, iron content, and vitamin A levels of chicken liver nuggets, as well as quantifying their impact on cholesterol reduction and microstructural stability. By integrating nutritional science with food engineering principles, this research seeks to establish a framework for developing functional meat products that leverage underutilized animal proteins while aligning with sustainable food systems (Chuyev et al., 2021). The findings will advance understanding of vegetable flours as multifunctional ingredients, addressing both malnutrition and food waste through innovative product design.

Materials and methods

1. Research materials

Fresh chicken liver was procured from a certified local poultry supplier to ensure consistent quality, as recommended in previous studies (Malichati & Adi, 2018). Vegetable-based flours cornstarch, soybean, pumpkin, and carrot were selected based on their documented potential to enhance nutritional and functional properties in meat products (Amertaningtyas et al., 2021).

Additional ingredients, including tapioca flour, eggs, breadcrumbs, garlic, salt, pepper, and water were incorporated to standardize the formulation across treatments. The inclusion of these ancillary components aligns with established protocols aimed at improving binding capacity, texture, and overall product stability (Jaya & Yusanti, 2018; Thohari et al., 2017).

To ensure clarity and reproducibility, Table 1 presents the detailed formulation of the chicken liver nuggets, including the percentage contributions of each ingredient relative to the liver content.

Table 1 Formulation of chicken liver nuggets with vegetable-based flours

No.	Ingredient	Ingredients weight (g)	Proportion of ingredients as percent of chicken liver (%)
1	Chicken liver	500	100
2	Tapioca flour	100	20
3	Treatment flour - Cornstarch (CS) - Soybean flour (SF) - Pumpkin flour (PF) - Carrot flour (CF)	25	5
4	Salt	15	3
5	Pepper	10	2
6	Garlic	20	4
7	Egg	75	15
8	Water	100	20

Remark: Composition of chicken liver nuggets with cornstarch, soybean, pumpkin, and carrot flours added at defined ratios. Percentages are expressed relative to chicken liver weight (100% = 500g) (adapted from Amertaningtyas et al., 2021; Marbun et al., 2018).

2. Research method

The study employed a randomized block design to systematically assess the effects of four different vegetable-based flours on the quality attributes of chicken liver nuggets. Each treatment group was replicated 5 times to ensure statistical robustness. The experimental groups included a control group (tapioca flour only) and 4 treatment groups, each receiving a 5% addition (relative to chicken liver weight) of either cornstarch, soybean, pumpkin, or carrot flour. This design facilitated a direct comparison among formulations while controlling for extraneous variability (Talukder et al., 2015). The concentration levels were selected based on preliminary trials and literature evidence supporting the optimal balance between nutritional enhancement and sensory acceptance (Ajibola et al., 2015).

3. Nugget preparation procedure

The preparation of chicken liver nuggets was conducted in sequential stages to ensure uniformity in processing. Initially, the chicken liver was steamed (Model HD9125, Philips, Netherlands) to mitigate its strong flavor and improve texture, following protocols similar to those described by Hamidiyah (2018). The steamed liver was then minced using a calibrated food processor (Model KFP0718, KitchenAid, USA) to achieve a homogeneous consistency.

Subsequently, the minced liver was combined with tapioca flour, the designated vegetable-based flour (cornstarch, soybean, pumpkin, or carrot flour), and other seasonings (salt, pepper, garlic), along with egg and water, to form a cohesive dough. The mixture was weighed using a digital balance (Model SF-400, Camry Electronic, China) and homogenized thoroughly using the same food processor to ensure even distribution of ingredients.

Once a uniform mixture was obtained, it was molded into nugget shapes using standardized plastic molds (Model PP-M01, PlastPack, Indonesia) to maintain consistency in size and weight across treatments. The molded nuggets underwent a secondary steaming process at 70°C for 20 min using a laboratory steamer (Model ST-20, Getra, Indonesia), a step critical for ensuring proper protein coagulation and minimizing residual off-flavors (Chuyev et al., 2021).

After steaming, the nuggets were cooled to room temperature, then dipped in egg white and coated in commercial breadcrumbs (Finna®, Indonesia), then deep-fried at 170°C for 2–3 min in a stainless-steel fryer (Model MF-30, Maspion ProChef, Indonesia) to achieve a golden-brown exterior. This 2-stage cooking process—steaming followed by frying—was selected to optimize nutritional retention and enhance the sensory attributes of the final product (Pereira et al., 2020).

4. Analytical methods

4.1 Nutritional and physicochemical analysis

The nutritional composition of the chicken liver nuggets was determined by analyzing parameters such as protein content, iron concentration, vitamin A levels, and cholesterol content. Iron was quantified using atomic absorption spectrophotometry (AAS) with a PerkinElmer AAnalyst 200 (PerkinElmer, USA), while vitamin A was measured via high-performance liquid chromatography (HPLC) using a Shimadzu Prominence HPLC System (Shimadzu Corporation, Japan), both validated in earlier studies (Urip et al., 2021). Cholesterol levels were assessed using an enzymatic colorimetric method with a UV–Vis spectrophotometer (UV-1800, Shimadzu, Japan), and protein content was determined through the Kjeldahl method using a KjelFlex K-360 unit (Buchi Labortechnik AG, Switzerland), following the Indonesian National Standard (National Standardization Agency of Indonesia, 2014) Antioxidant activity was evaluated using the DPPH radical scavenging assay on a microplate reader (BioTek Epoch™, USA), providing insight into the oxidative stability of the formulations (Setiawati et al., 2025). All analyses were performed in triplicate to ensure reproducibility and accuracy.

4.2 Amino acid profiling

The comprehensive amino acid composition of the nuggets was analyzed using ultra-performance liquid chromatography (UPLC) with an ACQUITY UPLC H-Class System (Waters Corporation, USA). This technique enabled precise quantification of both essential and non-essential amino acids, which is critical for assessing the nutritional value of the reformulated product. The system was calibrated using certified standard amino acid mixtures, and the analysis followed protocols consistent with previously published methodologies (Wulandari et al., 2019).

4.3 Microstructural analysis

The microstructural properties of the nuggets were investigated using scanning electron microscopy (SEM) with a JSM-6510LV (JEOL, Japan). This technique provided detailed images for evaluating the protein–starch network, porosity, and overall textural characteristics of the formulations. SEM analysis followed standard sample preparation procedures, including fixation, dehydration, and sputter-coating with gold to enhance image resolution. The resulting micrographs were analyzed to compare the compactness and porosity of nuggets across different treatment groups, offering insights into how each vegetable flour influences the final product's texture and moisture retention (Samard & Ryu, 2019)

4.4 Sensory evaluation

Sensory evaluation was conducted to assess the acceptability of chicken liver nuggets enriched with different vegetable-based flours compared to the control (tapioca flour only). A total of 30 untrained panelists (15 males and 15 females, aged 20–40 years) were recruited from the Department of Animal Science, Universitas Brawijaya. All participants had no known allergies to the tested ingredients and provided informed consent prior to participation.

Each panelist received coded samples of 5 nugget formulations: Control, CS (Cornstarch), SF (Soybean Flour), PF (Pumpkin Flour), and CF (Carrot Flour). Samples were served warm (approximately 45°C) in a randomized order using a completely randomized design (CRD). Evaluations were conducted in standard sensory booths, and panelists assessed five attributes—Color (appearance), Aroma (odor), Taste (flavor), Texture (mouthfeel), and Overall acceptability—using a 5-point hedonic scale (1 = dislike very much to 5 = like very much). Water was provided for rinsing between samples to prevent flavor carry-over. The entire session lasted approximately 30 min (Umam et al., 2018).

This sensory evaluation adhered to the ethical standards for research involving human participants. As the study involved minimal risk, was non-invasive, and used anonymized food samples, formal ethical approval was not required. Nevertheless, informed consent was obtained from all panelists in accordance with institutional ethical guidelines.

4.5 Statistical analysis

Statistical analyses were performed using analysis of variance (ANOVA) to determine the significance of differences in nutritional, physicochemical, and microstructural parameters, with a significance threshold set at $p<0.01$ (Talukder et al., 2015). Sensory data were analyzed using ANOVA followed by Tukey's HSD test at $p<0.05$. Post-hoc comparisons were conducted to identify specific differences between treatment means. All computations were carried out using IBM SPSS Statistics software, version 26.0 (IBM Corp., USA). Results are presented as mean ± standard deviation, to ensure a robust interpretation of data variability and statistical reliability. This analytical framework aligns with methodologies employed in recent meat product innovation studies (Borsolyuk & Verbytskyi, 2023).

Results and discussion

1. Nutritional composition and physicochemical properties

The nutritional analysis of the chicken liver nuggets revealed significant differences among formulations incorporating various vegetable-based flours (Table 2). Cornstarch addition yielded the highest iron content (31.53 ppm), though statistically comparable to soybean and carrot flours. This may be attributed to corn's inherent iron content and its potential to enhance bioavailability. The significantly higher iron levels in the cornstarch and soybean flour treatments compared to the control likely reflect the intrinsic mineral composition of these flours. Soybean flour, in particular, is naturally rich in iron and contains bioactive peptides and isoflavones that may enhance iron solubility and retention during processing. Thermal treatment may also liberate bound iron from plant matrices, increasing its measurable concentration. The lower iron in pumpkin flour could be due to dilution effects or reduced iron availability from its matrix (Behailu & Abebe, 2020; Urip et al., 2021).

Cholesterol levels varied significantly across treatments. Nuggets formulated with soybean and carrot flours showed marked reductions in cholesterol content (149.42 and 148.64 mg/100g, respectively) compared to those with cornstarch and pumpkin flour. This reduction may be attributed to the dietary fiber and bioactive compounds in carrots and soybeans that modulate lipid metabolism. Fiber may bind bile acids in the gut, promoting cholesterol excretion and reducing absorption. Additionally, phytosterols in soybeans can compete with cholesterol for intestinal uptake, resulting in lower measured values. In contrast, the control sample exhibited the highest cholesterol level, reflecting the unmodified lipid profile of chicken liver (Ajibola et al., 2015; Talukder, 2015).

Vitamin A levels also differed significantly among treatments. Nuggets enriched with pumpkin flour exhibited the highest concentration (1015.62 µg/100g), while those with carrot flour had the lowest concentration (662.99 µg/100g), despite carrots being known for their beta-carotene content. The elevated vitamin A in the pumpkin flour treatment is likely due to its high β-carotene concentration, a provitamin A compound that is efficiently retained during moderate heat processing. Carrot flour, although rich in β-carotene, may have experienced greater losses during processing. The control and other treatments showed moderate levels, reflecting the liver's natural vitamin A content, with enhancement from vegetable-based contributions (Marbun et al., 2018; Thohari et al., 2017).

Antioxidant activity, assessed via the DPPH assay, showed significant variation among treatments (Table 2). Nuggets enriched with pumpkin flour demonstrated the strongest antioxidant capacity, as indicated by the lowest IC_{50} value. Formulations with cornstarch, soybean, and carrot flours exhibited comparatively weaker scavenging effects. These results suggest that pumpkin flour contributes higher levels of antioxidant compounds such as carotenoids and phenolics, enhancing oxidative stability. The stability of these compounds during steaming and frying allows retention of bioactivity. Soybean and carrot flours also contributed antioxidant compounds—namely isoflavones and polyphenols—resulting in moderate antioxidant activity. The control sample, which lacked plant-based bioactives, exhibited the lowest antioxidant potential (Botella-Martínez et al., 2021; Kumar et al., 2015).

Table 2 Nutritional composition of chicken liver nuggets with the added vegetable-based flours (M ± SD)

Treatment	Iron (ppm)	Cholesterol (mg/100g)	Vitamin A (µg/100g)	Antioxidants IC_{50} (mg/mL)
Control	27.02±2.38[b]	213.69±1.65[a]	848.78±4.21[a]	318.66±1.53[a]
CS (Cornstarch)	31.53±4.23[a]	197.49±1.25[b]	959.05±4.13[a]	295.20±2.69[b]
SF (Soybean)	29.45±1.14[a]	149.42±1.20[c]	912.73±5.60[a]	263.43±1.15[bc]
PF (Pumpkin)	24.20±1.16[b]	202.66±1.67[ab]	1015.62±7.55[a]	162.23±3.33[c]
CF (Carrot)	30.65±3.46[a]	148.64±1.36[c]	662.99±5.45[b]	276.55±1.28[b]

Remark: Values in the same column followed by different superscript letters [(a-c)] indicate statistically significant differences between treatments ($p<0.05$) according to Tukey's HSD test.

The comprehensive amino acid composition of the chicken liver nuggets is summarized in Table 3, showing the distribution of both essential and non-essential amino acids across treatments. Amino acid profiling further confirmed that the incorporation of vegetable-based flours did not adversely affect the essential amino acid profile. *L*-Leucine was the most abundant essential amino acid, followed by *L*-Arginine and *L*-Phenylalanine, indicating a strong presence of branched-chain and aromatic amino acids critical for protein synthesis. Among the non-essential amino acids, *L*-Glutamic Acid was dominant, reinforcing its known contribution to umami taste (Ninomiya, 2015). These results demonstrate that vegetable-based flour incorporation preserved the amino acid balance of the nuggets, maintaining their nutritional integrity despite formulation changes (Shoaib et al., 2018; Thirumdas et al., 2018).

Table 3 Amino acid composition of nuggets with the addition of various vegetable-based flours

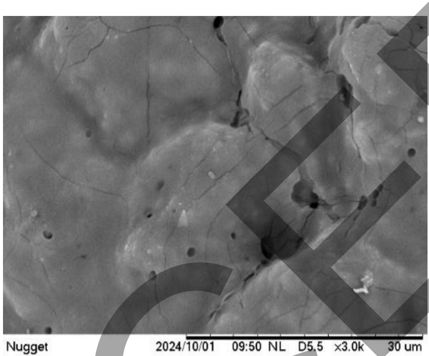
Amino acids	Type	Concentration (mg/kg)				
		Control	CS	SF	PF	CF
L-Leucine	Essential	8647.58	9236.06	10354.14	9409.84	8978.2
L-Arginine	Essential	7125.38	7275.46	9092.74	6164.23	5812.74
L-Phenylalanine	Essential	6981.67	7163.37	9143.93	5344.46	4817.92
L-Lysine	Essential	6687.42	6873.2	6119.35	7168.98	7464.7
L-Valine	Essential	6252.65	6368.04	6984.33	6666.8	6392.54
L-Threonine	Essential	5682.31	5948.67	6803.53	5269.13	4897.88
L-Isoleucine	Essential	4958.42	5141.16	5786.92	5273.56	5063.28
L-Histidine	Essential	3107.93	3298.67	4215.57	2697.69	2433.12
L-Glutamic Acid	Non-Essential	20462.36	20979.08	19565.15	19327.14	19393.13
L-Aspartic Acid	Non-Essential	9268.27	9531.07	8627.2	8853.8	9104.43
L-Proline	Non-Essential	6013.49	6167.72	6631.86	6083.13	5846.59
L-Alanine	Non-Essential	5764.21	5959.12	5801.86	5859.38	5939.8
Glycine	Non-Essential	5401.26	5629.68	6702.89	5392.65	5128.72
L-Serine	Non-Essential	4783.5	4939.51	6097.07	4701.43	4194.38
L-Tyrosine	Non-Essential	3349.76	3526.33	4437.02	2622.66	2438.02

These findings align with previous research demonstrating the effectiveness of vegetable flours in enhancing the nutritional profiles of meat products. For instance, Aslinah et al. (2018) reported that adzuki bean flour, when used as a meat extender and fat replacer in beef meatballs, not only improved nutritional quality but also enhanced oxidative stability. Similarly, Ball et al. (2021) noted that the incorporation of plant-based proteins into ground beef patties positively influenced both fresh and cooked product characteristics. The present results extend these observations to chicken liver nuggets, reinforcing the role of vegetable-based flours as functional ingredients in meat product formulation.

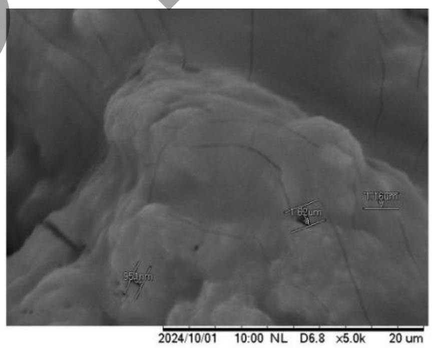
2. Microstructural properties

Scanning Electron Microscopy (SEM) was employed to assess the microstructural changes induced by the incorporation of different vegetable-based flours. The SEM images revealed distinct textural differences among the formulations (Fig. 1). Nuggets formulated with cornstarch displayed a compact and uniform microstructure, indicative of effective gel formation and strong binding interactions between the protein and starch components. In contrast, formulations containing soybean and carrot flours exhibited a more porous structure with visible cavities. This increased porosity likely results from the lower starch content and the unique protein–fiber interactions associated with these vegetable flours (Samard & Ryu, 2019).

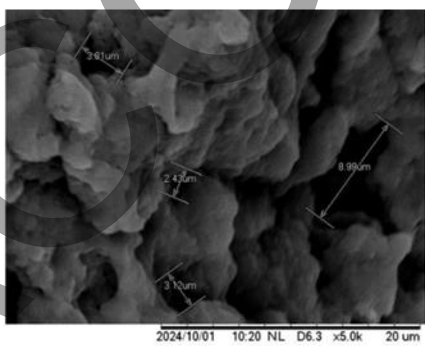
Pumpkin flour-based nuggets demonstrated an intermediate microstructure, characterized by moderately compact regions interspersed with porous areas. These microstructural variations are critical, as they influence water retention, texture, and overall sensory quality. A compact structure, as seen in cornstarch formulation, may contribute to improved mechanical strength and reduced moisture loss during cooking. Conversely, a porous structure could enhance juiciness and tenderness, albeit at the potential expense of structural integrity (Ganie et al., 2017; Gupta et al., 2021).



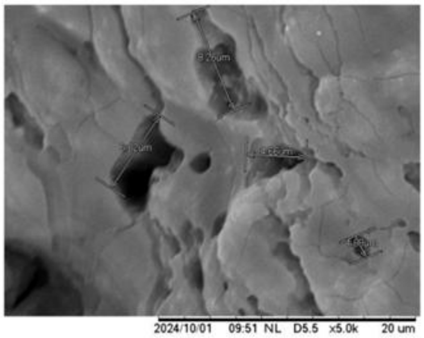
(a)



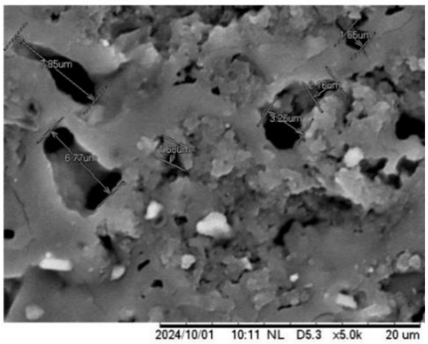
(b)



(c)



(d)



(e)

Fig. 1 Representative SEM micrographs of chicken liver nuggets. SEM images illustrate the microstructural differences among chicken liver nuggets formulated with (a) tapioca flour only (b) cornstarch, (c) soybean flour, (d) pumpkin flour, and (e) carrot flour. The image for (b) shows a compact structure, whereas images (a), (c), (d), and (e) reveal increased porosity.

These structural observations are consistent with findings from related studies. For example, Kotecka-Majchrzak et al. (2021) demonstrated that incorporating hemp cake into meatballs resulted in a porous microstructure, which correlated with improved moisture retention and sensory appeal. Similarly, studies by Ogundipe et al. (2023) and Suychinov et al. (2023) reported that plant-based flours significantly influence the microstructure of meat patties, thereby affecting their textural properties. The current SEM analysis confirms that strategic ingredient selection is essential for achieving an optimal balance between texture and nutritional enhancement in meat formulations.

3. Holistic evaluation of nutritional and structural attributes

The integration of vegetable-based flours into chicken liver nuggets offers a multifaceted approach to addressing both nutritional deficiencies and sensory limitations. The experimental results indicate that each type of vegetable flour confers distinct advantages. Cornstarch effectively enhances iron content, which is critical in addressing iron-deficiency anemia—a significant global health concern (Behailu & Abebe, 2020; Urip et al., 2021). Meanwhile, pumpkin flour contributes to elevated vitamin A levels and reduced cholesterol content, offering an attractive nutritional profile for health-conscious consumers (Marbun et al*.,* 2018; Thohari et al*.,* 2017).

Physicochemical improvements observed in the formulations, such as enhanced antioxidant activity with pumpkin flour, are particularly noteworthy. Antioxidants play a crucial role in inhibiting lipid oxidation, thereby extending shelf life and maintaining product quality during storage and distribution (Botella-Martínez et al., 2021; Kumar et al*.,* 2015). The synergy between nutritional enhancement (iron from cornstarch and soybean flour) and structural stability (cornstarch's compact matrix) underscores the potential of vegetable flours to address both health and consumer acceptability challenges. These improvements are consistent with findings from Shahamirian et al. (2019), who reported that natural extracts and alternative flours could significantly enhance the oxidative stability of meat products.

Moreover, the balanced amino acid profiles across all treatments suggest that the nutritional quality of chicken liver is preserved despite the addition of plant-based ingredients—a finding that aligns with the work of Shoaib et al. (2018) and Thirumdas et al., (2018). Previous research on fermented goat meat demonstrated that manipulating L. *plantarum* levels significantly altered the physicochemical characteristics, including pH, water activity, and tenderness (Umam et al., 2019; Radiati et al., 2020). A similar mechanism may mediate the effects of flour incorporation in this study, particularly with pumpkin and cornstarch enhancing texture and moisture retention.

From a microstructural perspective, SEM analysis provided clear evidence that the choice of vegetable flour influences the textural properties of the nuggets. The compact structure observed in cornstarch formulations correlates with enhanced mechanical strength and moisture retention, whereas the porous structure associated with soybean and carrot flours may contribute to improved juiciness and tenderness (Samard & Ryu, 2019). These structural variations are essential for optimizing both the sensory and functional attributes of the final product, as highlighted by studies on meat analogues and extenders (Kotecka-Majchrzak et al., 2021; Ogundipe et al., 2023).

4. Sensory evaluation

The sensory evaluation, although preliminary, supports the potential consumer acceptability of the optimized formulations. As shown in Table 4, chicken liver nuggets formulated with cornstarch (CS) received the highest acceptability scores across all attributes, particularly in taste, texture, and overall impression. This suggests that cornstarch effectively enhanced sensory quality by masking the strong flavor of the liver and contributing to a smoother texture. The control sample (formulated with tapioca flour) showed moderate scores, indicating an acceptable baseline but with room for improvement. In contrast, nuggets with pumpkin (PF) and carrot flour (CF) scored lower, especially in aroma and texture, likely due to their stronger flavors and higher fiber content affecting product consistency. Nuggets with soybean flour (SF) received moderate acceptance, although the beany flavor may have influenced consumer preference. These findings highlight the importance of selecting vegetable-based flours not only for their nutritional benefits but also for their impact on sensory attributes.

Table 4 Sensory evaluation results for chicken liver nuggets with different vegetable-based flours

Treatment	Color	Taste	Aroma	Texture	Overall
Control	3.25 ± 1.10^{ab}	3.50 ± 0.95^{ab}	3.60 ± 1.00^{b}	3.30 ± 1.05^{ab}	3.45 ± 1.08^{b}
CS	3.68 ± 1.23^{a}	4.00 ± 0.96^{a}	4.40 ± 1.10^{a}	3.80 ± 1.20^{a}	4.05 ± 1.15^{a}
SF	2.79 ± 1.08^{b}	2.93 ± 1.10^{b}	3.07 ± 1.07^{c}	3.00 ± 1.15^{b}	2.85 ± 1.10^{c}
PF	2.61 ± 1.14^{b}	2.71 ± 0.84^{b}	2.61 ± 0.67^{c}	2.80 ± 1.10^{b}	2.65 ± 1.05^{c}
CF	2.43 ± 1.08^{b}	2.32 ± 1.04^{b}	2.82 ± 1.14^{c}	2.90 ± 1.10^{b}	2.70 ± 1.15^{c}

Remark: Different superscripts $^{(a\text{-}c)}$ indicate statistically significant differences ($p<0.05$) according to Tukey's HSD test. M ± SD represents the average scores from sensory evaluations conducted by 30 panelists.

The improved texture and balanced flavor profile—particularly in nuggets incorporating soybean and pumpkin flours—demonstrate successful mitigation of the inherent strong flavor of chicken liver. Such enhancements are vital in transforming an underutilized yet nutritionally rich ingredient into a commercially viable product (Marconato et al., 2020; Richa et al., 2021). The strategic incorporation of plant-based flours not only improved physicochemical properties but also offered potential functional benefits. Previous studies have shown that alternative starches, such as canna starch (*Canna edulis* Ker), act as effective hydrocolloids in dairy-based fermented beverages, enhancing texture stability and product consistency (Umam et al., 2019). This suggests that carbohydrate-rich flours may likewise contribute to improved matrix integrity in meat products.

Beyond textural improvements, antioxidant activity has emerged as a focal point in functional food research. A recent study on goat milk kefir demonstrated how processing stages influence antioxidant capacity and peptide content during cold storage, underscoring the importance of matrix manipulation to preserve bioactive components (Umam et al., 2022). Additionally, the health-promoting effects of fermented dairy exopolysaccharides—particularly their anti-obesity potential through inhibition of adipogenesis enzymes—reinforce the rationale for using functional plant-derived ingredients in meat-based formulations aligned with nutritional and health trends (Radiati et al., 2025).

Integrating these findings with the broader literature, it is evident that vegetable-based flours can significantly contribute to the development of functional meat products. Enhanced nutritional attributes, such as increased iron and vitamin A levels and reduced cholesterol, address major health concerns and align with global dietary improvement initiatives (Borsolyuk & Verbytskyi, 2023; Muliani et al., 2021). Technological benefits, including antioxidant activity and microstructural integrity, further support the formulation's industry potential, as corroborated by studies on alternative fat substitutes and natural antioxidants (Kolev et al., 2022).

The current study's integrated approach combining nutritional, physicochemical, and microstructural assessments offers a holistic understanding of how vegetable-based flours can be leveraged to create superior meat products. This aligns with recent trends in food technology research, where multi-dimensional evaluations are increasingly used to address complex formulation challenges (Dominguez-Hernandez et al., 2018; Fiorentini et al., 2020). The evidence presented here supports the hypothesis that vegetable flours can improve both the nutritional and sensory properties of chicken liver nuggets and lays the groundwork for future studies aimed at optimizing ingredient ratios and processing conditions.

Overall, the study demonstrates that targeted ingredient modifications—specifically, the use of vegetable-based flours can overcome traditional limitations associated with chicken liver utilization. This advancement contributes meaningfully to the development of healthier and more sustainable meat products, addressing critical nutritional deficiencies and meeting evolving consumer demands in the global food market (Ruedt et al., 2021; Teryokhina et al., 2022).

Conclusion

This study demonstrated that the strategic incorporation of vegetable-based flours into chicken liver nuggets significantly improved nutritional quality and physicochemical properties compared to the control formulation (tapioca flour only). Specifically, cornstarch significantly increased iron content, pumpkin flour enhanced vitamin A levels and reduced cholesterol, and both contributed to improved antioxidant capacity. Microstructural analyses further confirmed that each flour type uniquely influenced the texture and moisture retention, positively affecting overall sensory acceptance.

These findings highlight the potential of functional flours to overcome limitations associated with liver-based meat products, offering a promising pathway toward healthier and more consumer-friendly formulations. Further research is recommended to evaluate the effects of flour combinations on taste, nutritional value, and consumer preference. Such investigations will support the broader application of vegetable flours in reducing food waste and addressing nutrient deficiencies, thereby advancing health-oriented product development and sustainability goals.

Acknowledgements

This research was supported by the Faculty of Animal Science, Universitas Brawijaya through the Visiting Lecturer Universitas Brawijaya Programme for 2025, under the Decision of the Rector of Universitas Brawijaya (No. 1115/2025) and the Invitation to Join Universitas Brawijaya as a Visiting Lecturer (No. 01798/UN10.A0101/B/TU/2025).

Conflict of interest

The authors declare no conflict of interest.

Declaration of generative ai and ai-assisted technologies in the writing process

The authors declare that no generative artificial intelligence tools were used in the writing or preparation of this manuscript.

References

Ajibola, C.F., Oyerinde, V.O., & Adeniyan, O.S. (2015). Physicochemical and antioxidant properties of whole-wheat biscuits incorporated with *Moringa oleifera* leaves and cocoa powder. *Journal of Scientific Research and Reports, 7*(3), 195–206.

Amertaningtyas, D., Gusmaryani, S., Fasha, N.N., Evanuarini, H., & Apriliyani, M.W. (2021). The use of wheat flour and tapioca flour in chicken liver nuggets and beef liver nuggets. *Journal of Animal Science, Padjadjaran University*, *21*(2), 143–151. https://doi.org/10.24198/jit.v21i2.36613

Aslinah, L.N.F., Mat Yusoff, M., & Ismail-Fitry, M.R. (2018). Simultaneous use of adzuki beans (*Vigna angularis*) flour as meat extender and fat replacer in reduced-fat beef meatballs (*bebola daging*). *Journal of Food Science and Technology, 55*(8), 3241–3248.

Ball, J.J., Wyatt, R.P., Lambert, B.D., Smith, H.R., Reyes, T.M., & Sawyer, J.T. (2021). Influence of plant-based proteins on the fresh and cooked characteristics of ground beef patties. *Foods, 10*(9), 1971.

Behailu, B., & Abebe, M. (2020). Effect of soybean and finger millet flours on the physicochemical and sensory quality of beef meat sausage. *Asian Journal of Chemical Sciences, 7*(1), 6–14.

Borsolyuk, L., & Verbytskyi, S. (2023). Scientific basics to develop functional meat pâtés. *Ukrainian Black Sea Region Agrarian Science, 27*(3), 71–79.

Botella-Martínez, C., Lucas-Gonzalez, R., Ballester-Costa, C., Pérez-Álvarez, J.Á., Fernández-López, J., Delgado-Ospina, J., ... Viuda-Martos, M. (2021). Ghanaian cocoa (*Theobroma cacao* L.) bean shells coproducts: Effect of particle size on chemical composition, bioactive compound content and antioxidant activity. *Agronomy*, *11*(2), 401.https://doi.org/10.3390/agronomy11020401

Chuyev, S.A., Mezinova, K.V., Ryadinskaya, A.A., Ordina, N.B., Koshchayev, I.A., & Zakharova, D.A. (2021). Formulation development of original canned meat and vegetables for healthy nutrition. *BIO Web of Conferences, 32*(1), 03011.

Dominguez-Hernandez, E., Salaseviciene, A., & Ertbjerg, P. (2018). Low-temperature long-time cooking of meat: Eating quality and underlying mechanisms. *Meat Science, 143*, 104–113.

Fiorentini, M., Kinchla, A.J., & Nolden, A.A. (2020). Role of sensory evaluation in consumer acceptance of plant-based meat analogs and meat extenders: A scoping review. *Foods, 9*(9), 1334.

Ganie, L.A., Kumar, A., & Tanwar, T. (2017). Quality traits of low-sodium fish balls incorporated with barley flour and pea flour. *Journal of Environmental Biology, 38*(5), 815–819.

Gupta, S., Sharma, B.D., & Mendiratta, S.K. (2021). Effect of barley flour on quality of restructured spent hen meat blocks. *Indian Journal of Animal Research, 55*(10), 1255–1259.

Hamidiyah, A. (2018). Composition of chicken liver nugget to organoleptic and hemoglobin levels in the efforts to prevent adolescent female anemia. In *International Conference on Sustainable Health Promotion* (pp. 114–118), Bologna, Italy.

Jaya, F.M., & Yusanti, I.A. (2018). Different formulations of Patin fish surimi and carrot puree on the proximatic quality of fish nugget. *Journal Enggano, 3*(1), 1–9.

Kartikasari, L., Hertanto, B., & Nuhriawangsa, A. (2023). Omega-3 profiles and chemical substances of chicken meat fed diets containing purslane (*Portulaca oleraceae*) meal rich in omega-3 fats. *Food Research*, *7*(1), 35–41.

Kolev, N., Vlahova-Vangelova, D., Balev, D., & Dragoev, S. (2022). Quality changes of cooked sausages influenced by the incorporation of a three-component natural antioxidant blend. *BIO Web of Conferences*, *45*, 01006.

Kotecka-Majchrzak, K., Kasałka-Czarna, N., Montowska, M., Spychaj, A., & Mikołajczak, B. (2021). The effect of hemp cake (*Cannabis sativa* L.) on the characteristics of meatballs stored in refrigerated conditions. *Molecules, 26*(17), 5284.

Kumar, Y., Yadav, D.N., Ahmad, T., & Narsaiah, K. (2015). Recent trends in the use of natural antioxidants for meat and meat products. *Comprehensive Reviews in Food Science and Food Safety, 14*(6), 796–812.

Malichati, A.R., & Adi, A.C. (2018). Instant chicken broth with chicken liver flour substitution as an alternative seasoning to prevent anemia. *Amerta Nutrition*, *2*(1), 74–82.

Marbun, E.D., Sinaga, L.A., Simanjuntak, E.R., Siregar, D., & Afriany, J. (2018). Penerapan metode weighted aggregated sum product assessment dalam menentukan tepung terbaik untuk memproduksi bihun. *Journal of Computer Research (JURIKOM), 5*(1), 24–28.

Marconato, A.M., Hartmann, G.L., Santos, M.M.R., do Amaral, L.A., de Souza, G.H.O., dos Santos, E.F., & Novello, D. (2020). Sweet potato peel flour in hamburger: Effect on physicochemical, technological and sensorial characteristics. *Brazilian Journal of Food Technology, 23*, e2019115.

Muliani, D., Nathania, E.A., Jayanti, Y.N., & Hadrian, E. (2021). Food innovation: Fungi and vegetables potential as a healthy and sustainable meat substitute. *Indonesian Journal of Life Sciences, 3*(2), 1–27.

National Standardization Agency of Indonesia (BSN). (2014). *Indonesian National Standard: Naget ayam (Chicken nugget)* (SNI 6683:2014). National Standardization Agency of Indonesia (BSN).

Ninomiya, K. (2015). Science of umami taste: Adaptation to gastronomic culture. *Flavour, 4*(1), 13.

Ogundipe, O.O., Fasogbon, B.M., Ayeke, A.O., Nwosu, P.N., Adebayo-Oyetoro, A.O., & Faloye, O.R (2023). Quality evaluation of beef patties formulated with wheat and sweet potato flour blends. *Food Science and Applied Biotechnology, 6*(2), 187–199.

Pereira, J., Brohi, S.A., Malairaj, S., Zhang, W., & Zhou, G.H. (2020). Quality of fat-reduced frankfurter formulated with unripe banana by-products and pre-emulsified sunflower oil. *International Journal of Food Properties, 23*(1), 420–433.

Radiati, L.E., Damayanthi, E., Armaini, A., Santoso, A., Hati, D.L., Fardiaz, D., ... & Umam, A.K. (2025). Exopolysaccharide of goat milk kefir as an anti-obesity agent: Inhibition of adipogenesis enzyme activity on 3T3-L1 adipocyte model cells. *Journal of Advanced Pharmaceutical Technology & Research*, *16*(2), 47–52

Radiati, L.E., Umam, A.K., Susilo, A. & Thoifi, A.A., (2020). Effect of *Lactobacillus plantarum* concentration level on physicochemical properties of fermented goat meat dendeng. *IOP Conference Series: Earth and Environmental Science*, *478*(1), 012038. https://doi.org/10.1088/1755-1315/478/1/012038

Richa, K., Laskar, S.K., Das, A., Hazarika, M., Choudhury, S., Sonowal, S., & Upadhyay, S. (2021). Evaluation of certain physico-chemical and sensory qualities of chicken nuggets incorporated with black rice (*Oryza sativa* L.) flour. *Asian Journal of Dairy and Food Research, 43*, 723–727.

Ruedt, C., Gibis, M., & Weiss, J. (2021). Influence of muscle type and microstructure on iridescence in cooked, cured pork meat products. *Journal of Food Science, 86*(8), 3563–3573.

Samard, S., & Ryu, G.H. (2019). A comparison of physicochemical characteristics, texture, and structure of meat analogue and meats. *Journal of the Science of Food and Agriculture, 99*(6), 2708–2715.

Setiawati, A.R., Amertaningtyas, D., & Umam, A.K. (2025). Effect of adding kaffir lime leaf powder (*Citrus hystrix*) and citronella leaf powder (*Cymbopogon nardus*) in salted egg on pH, antioxidant, moisture content, and organoleptics. *Journal of Animal Science and Technology*, *20*(1), 61–75.

Shahamirian, M., Eskandari, M.H., Niakousari, M., Esteghlal, S., Hashemi Gahruie, H., & Mousavi Khaneghah, A. (2019). Incorporation of pomegranate rind powder extract and pomegranate juice into frozen burgers: Oxidative stability, sensorial and microbiological characteristics. *Journal of Food Science and Technology, 56*(3), 1174–1183.

Shoaib, A., Sahar, A., Sameen, A., Saleem, A., & Tahir, A.T. (2018). Use of pea and rice protein isolates as source of meat extenders in the development of chicken nuggets. *Journal of Food Processing and Preservation, 42*(9), e13763.

Soji-Mbongo, Z., & Mpendulo, T.C. (2024). Knowledge gaps on the utilization of fossil shell flour in beef production: A review. *Animals, 14*(2), 333.

Suychinov, A.K., Zhumanova, G.T., Mironova, I.V., Akhmadullina, E.T., Kadirov, N.N., Galiyeva, Z.A., & Neverova, O.V. (2023). Investigation of the chemical composition, physicochemical properties, and microstructure of meat patties with amaranth flour. *Theory and Practice of Meat Processing, 8*(3), 183–190.

Talukder, S. (2015). Effect of dietary fiber on properties and acceptance of meat products: A review. *Critical Reviews in Food Science and Nutrition, 55*(7), 1005–1011.

Talukder, S., Mendiratta, S.K., Soni, A., Singh, T.P., Chhangte, L., Kumar, R.R., ... & A, I. (2015). Development and quality characterization of mutton snack. *Nutrition and Food Science, 45*(6), 873–882.

Teryokhina, A.V., Kurchaeva, E.E., Popova, Y.A., Uhina, E.Y., Maksimov, I.V., & Bailova, N.V. (2022). The use of ginger rhizome in the production of meat products based on poultry and rabbit meat. *IOP Conference Series: Earth and Environmental Science, 1052*(1), 012079.

Thirumdas, R., Brnčić, M., Brnčić, S.R., Barba, F.J., Gálvez, F., Zamuz, ... & Lorenzo, J.M. (2018). Evaluating the impact of vegetal and microalgae protein sources on proximate composition, amino acid profile, and physicochemical properties of fermented Spanish "chorizo" sausages. *Journal of Food Processing and Preservation, 42*(11), e13817.

Thohari, I., Padaga, M.C., & Rahayu, P.P. (2017). *Teknologi hasil ternak (Livestock Product Technology)*. Brawijaya University Press.

Umam, A.K., Lin, M.J., Radiati, L.E., & Peng, S.Y. (2018). The utilization of canna starch (*Canna edulis Ker*) as an alternative hydrocolloid in the manufacturing process of yogurt drink. *Journal of Animal Science and Technology*, *13*(1), 1–13.

Umam, A.K., Radiati, L.E., Susila, A. & Hapsari, R.N., (2019). Chemical and microbiological quality of fermented goat meat dendeng with different levels of *L. plantarum*. *IOP Conference Series: Earth and Environmental Science, 387*(1), 012012. https://doi.org/10.1088/1755-1315/387/1/012012

Umam, A.K., Radiati, L.E., Suwondo, K.H.P., & Kholidah, S.N. (2022). Study of antioxidant activity, peptides, and chemical quality of goat milk kefir on the different post-acidification periods during cold storage. *Advances in Biological Sciences Research. 18,* 178–181.

Urip, U., Ariami, P., & Zaetun, S. (2021). Utilization of natural processed products (Red spinach tea, *Amaranthus tricolor* L.) in increasing hemoglobin levels in pregnant women in *Dasan Cermen* village, Mataram. *Bakti Sekawan: Journal of Community Service, 1*(2), 41–45.

Wulandari, D., Erwanto, Y., Pranoto, Y., Rusman, R., & Yuliatmo, R. (2019). Improvement of bovine split hide gelatin quality by addition of soy protein isolate using transglutaminase enzyme. *Tropical Animal Science Journal*, *42*(3), 237–244. https://doi.org/10.5398/tasj.2019.42.3.23

Article info

Amertaningtyas et al.

Received : 10 June 2025
Revised : 3 November 2025
Accepted : 4 November 2025