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Extruded Snack Sticks Incorporated with Chicken Heart and Liver for Enhanced Nutritional and Functional Properties

Abhinandh K.[1], Pavan Kumar[1*], Nandishwar[1], Nitin Mehta[1] and Amit Sharma[2]

[1]Department of Livestock Products Technology, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana 141004, INDIA
[2]Department of Animal Nutrition, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana 141004, INDIA

*Corresponding Author: pavankumar@gadvasu.in

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Abstract

The present study was undertaken to evaluate the nutritional and functional quality of extruded sticks by incorporating chicken heart (CH) and chicken liver (CL) byproducts. Based on preliminary trials, 4%, 6%, and 8% inclusion levels of chicken heart and liver byproducts were added into the basic formulation by replacing flours, thereby developing four variants: C (control, without CH and CL), T1 (2% CH and 2% CL), T2 (3% CH and 3% CL), and T3 (4% CH and 4% CL). The extruded sticks were evaluated for various physico-chemical, proximate, colour, and sensory attributes. The increasing levels of CH and CL at the highest levels (T3 sticks) resulted in a significant (p<0.05) increase in pH, water activity, protein, fat, and ash content of the formulated snacks. The treated products became darker with the incorporation of CH and CL, showing a significant (p < 0.05) reduction in lightness (L) values. The yellowness (b*) value of the control sample was significantly (p<0.05) higher than that of the treated samples. Sensory analysis demonstrated that the extruded sticks prepared with 3% CH and 3% CL (T2 sticks) were rated the highest overall acceptability. Thus, good-quality, protein-enriched extruded sticks can be successfully developed by incorporating 3% CH and 3% CL.*

Keywords: Chicken Heart, Chicken Liver, Edible byproducts, Extrusion, Quality Evaluation.

Introduction

The poultry industry, which produces approximately 137.98 million metric tonnes of meat (Global Meat Production 2024), serves as a significant source of global animal protein. During poultry slaughter and processing, several nutrient-dense byproducts are generated with immense potential for incorporation into value-added products. Various factors, including religious beliefs, consumer preferences, and cultural practices, influence the utilisation of slaughterhouse by-products (Alao *et al*., 2017). Due to the rapid expansion of poultry farming, there is an increased supply of spent and culled hens. The marketing of such birds poses a significant challenge to the meat industry (Kumar *et al*., 2012a). By applying suitable technological interventions such as mincing and extrusion, the tough and less tender meat obtained from these spent or culled birds is utilised in the preparation of various value-added meat products (Kumar *et al*. 2012 b; Mahajan *et al*., 2017; Malav *et al*., 2017).

The production of edible byproducts from spent and culled birds could also be judiciously used for the preparation of various value-added products (Umaraw *et al*., 2025). Edible byproducts derived from chickens constitute a considerable portion of the live weight, representing a readily available resource that offers promising opportunities for meat processors to enhance economic returns and minimize the wastage of this valuable source of nutrition and revenue (Seong *et al*., 2015). The utilisation of poultry slaughter byproducts could improve the economy of processing nutrient-rich tissues from feed or low-value outlets into human food, resulting in improved carcass value and decreasing reliance on high-cost meat (Yessimbekov *et al*., 2025). Among the poultry slaughter byproducts, liver and heart are very important and widely used edible byproducts. Chicken liver and heart comprise about 1.6–2.3% and 0.4-0.8% of the bird's live weight, respectively (Ockerman and Basu 2004). Heart and liver byproducts are a rich source of Coenzyme Q10. Heart muscles are rich in lysine, leucine, threonine, and tryptophan amino acids (Alao *et al*., 2017). Liver proteins contain high-quality water-soluble proteins that exert functional properties (Zouari *et al*., 2011; Steen *et al*., 2016). However, these byproducts are prone to spoilage due to their slow rate of chilling, primarily attributed to the adipose tissue and connective tissue covering, as well as their high moisture content.

The current snack market is predominantly occupied by starch-based products formulated from conventional sources, such as corn, wheat, rice, potatoes, cassava, and sweet potatoes (Rostamabadi *et al*., 2023; Patil *et al*., 2025). However, these products are generally low in protein, minerals, and dietary fibre (Grasso 2020; Kumar *et al*., 2019). The incorporation of edible chicken by-products into starch-based formulations enhances nutritional quality while promoting efficient utilisation of slaughterhouse waste through value addition in extruded product development.

Extrusion technology is a versatile, cost-effective, energy-efficient, and environmentally friendly process that enables the production of diverse, high-quality food products with minimal nutrient loss (Kumar *et al*., 2022); however, excessive heat and low moisture conditions can lead to colour fading, non-enzymatic browning, and nutritional deterioration of proteins such as lysine (Choton *et al*., 2020). Through extrusion, it is possible to achieve an optimal balance between product quality and nutritional retention, particularly in the formulation of value-added, protein-enriched snacks incorporating chicken heart and liver by-products.

Materials and Methods

Raw Materials

Spent hens older than 72 weeks were collected from the Directorate of Livestock Farm, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India. The birds were processed under humane conditions at the university's experimental slaughter facility by following standard protocols. During evisceration, giblets such as the heart, liver, and gizzard were removed, thoroughly washed, and classified. The heart and liver tissue were minced separately, sealed in low-density polyethylene bags, and preserved at -18 ± 1°C until use. Other ingredients used for preparing the extruded sticks, viz., refined wheat flour, rice flour, salt, refined oil, and spices, were sourced from a local market.

Preparation of Extruded Sticks

Based on preliminary trials, three inclusion levels (2, 3, and 4% each) of minced chicken heart (CH) and liver (CL) were selected for the preparation of extruded sticks. Four formulations of extruded sticks were prepared: Control (without CH and CL), T1 (2% CH + 2% CL), T2 (3% CH + 3% CL), and T3 (4% CH + 4% CL) (Table 1). The detailed processing steps for preparing extruded sticks are illustrated in the flow diagram presented in Figure 1.

Mixing refined wheat flour, rice flour, salt, spices, and refined vegetable oil
↓
Adding water and minced chicken heart and liver
↓
Grind for 4.5 min to make uniform dough (Wonder Maxie Plus)
↓
Dough
↓
Extrusion of dough on the tray lined with aluminium in stick form
↓
Hot air oven cooking (180 °C for 15 minutes)
↓
Tempering at room temperature
↓
Evaluation, storage and sample analysis

Fig. 1: Flowchart for the preparation of extruded sticks incorporated with chicken heart and liver byproducts

Table 1: Formulation for the preparation of extruded sticks incorporated with chicken heart and liver

Ingredients (%)	Control	T1	T2	T3
Refined wheat flour	33.0	31.0	30.0	29.0
Rice flour	33.0	31.0	30.0	29.0
Water	26.0	26.0	26.0	26.0
Refined vegetable oil	5.0	5.0	5.0	5.0
Spices	1.5	1.5	1.5	1.5
Salt	1.5	1.5	1.5	1.5
Chicken heart	-	2.0	3.0	4.0
Chicken liver	-	2.0	3.0	4.0

T1-extruded sticks with 2% minced chicken heart + 2% minced chicken liver, T2-extruded sticks with 3% minced chicken heart + 3% minced chicken liver, T3- extruded sticks with 4% minced chicken heart + 4% minced chicken liver.

Proximate Composition

The moisture content of the dough and prepared sticks was determined using an automatic moisture analyser (AMD MX-50, Essae®, Japan) by heating approximately 2 g of sample for 4 min at 105 °C. The fat content of the samples was analysed by the Soxhlet extraction method (SOCS PLUS SCS 6, Pelican Equipment, India) using petroleum ether as the solvent (boiling range 40–60 °C). Protein content was estimated using the Kjeldahl method (protein content=Nitrogen × 6.25). The ash content was assessed by incinerating the samples in a muffle furnace for 16 h, with the temperature gradually increased from 150 °C to 600 °C using quartz crucibles. All analytical procedures were performed according to the standard methods of the Association of Official Analytical Chemists (AOAC, 2000). The cooking yield (%) was calculated as the ratio of the cooked product weight to the raw product weight, expressed as a percentage.

$$\text{Cooking yield (\%)} = [\text{Weight of cooked product / Weight of raw product}] \times 100$$

$$\text{Cooking loss (\%)} = 100 - \text{cooking yield (\%)}$$

pH Measurement

The developed stick sample (1 g) was homogenised with 10 mL of distilled water using a pestle and mortar. The hydrogen ion concentration of the homogenate was measured using a digital pH meter (SAB 5000, LABINDIA, Mumbai), which had been pre-calibrated at room temperature with standard buffer solutions of pH 4.0, 7.0, and 9.0.

Water Activity

The water activity (a_w) of the developed sticks was measured using a Water Activity Meter (Model WA-16 DA) according to standard procedures to determine the availability of unbound water in the product.

Instrumental Colour Profile Analysis

The colour attributes of the developed sticks were evaluated using a Chroma Meter (CR-300, Konica Minolta, Japan). The colour coordinates were expressed as L^* (lightness), a^* (redness/greenness), and b^* (yellowness/blueness). Before measurement, the instrument was calibrated using the standard white calibration plate (CY-88.1, CX-0.3146, Cy-0.3210, D65 Y-88.1, D65 X-0.3171, D65y-0.3338) supplied by the manufacturer. The hue angle and chroma values were subsequently calculated using the formulas described by Froehlich *et al.* (1983).

Sensory Evaluation

The sensory characteristics of the developed sticks were evaluated by an experienced sensory panel comprising seven members, including postgraduate students and faculty from the department. The panellists assessed the samples for appearance and colour, flavour, crispiness, texture and overall acceptability using a 8-point descriptive scale, where 8 indicated "extremely desirable" and 1 indicated "extremely undesirable" (ISO 3972:2011, SS-EN ISO 8586:2014). Samples were served on white melamine plates and coded with random three-digit numbers to ensure unbiased evaluation. Potable water was provided to the panelists for mouth rinsing between samples to eliminate carryover effects.

Statistical Analysis

The experimental data were statistically analysed using IBM SPSS Statistics (Version 26.0; IBM Corp., USA) and expressed as Mean ± Standard Error. The entire experiment was conducted in triplicate, with duplicate samples analysed for each parameter ($n = 6$), except for sensory evaluation ($n = 21$). Analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) was performed to determine significant differences among treatments at a 95% confidence level ($p < 0.05$), as described by Snedecor and Cochran (1994). For sensory evaluation data, the non-parametric Friedman test was applied to assess differences in mean rank and median values.

Results and Discussion

Physicochemical and Proximate Parameters

Minced Heart and Liver

In the present study, the chicken heart (CH) exhibited a moisture content of 75.02 ± 0.37%, a water activity of 0.93 ± 0.06, a protein content of 16.85 ± 0.23%, a fat content of 6.78 ± 0.38%, and an ash content of 1.97 ± 0.07%. Seong *et al.* (2015) found that chicken heart contains 77.36 ± 0.38% moisture, 4.53 ± 0.13% fat, and 13.83 ± 0.12% protein. The chicken liver by-product (CL), on the other hand, contained 71.76 ± 0.57% moisture, 0.92 ± 0.24 water activity, 6.74 ± 0.12 pH value, 20.25±0.37% protein, and 3.08±0.49% fat. These findings are in close agreement with the values reported by Henry *et al.* (2019), who observed the proximate compositions of chicken liver to be 73.31 ± 0.05% moisture, 18.20 ± 0.30% protein, 4.36 ± 0.01% fat, and 1.42 ± 0.01% ash. Yessimbekov *et al.* (2025) also reported 75.88% moisture, 16.30% protein, 6.22% fat, and 1.60% ash content in fresh chicken heart.

Raw Dough Characteristics

The incorporation of minced CH and CL influenced the moisture content and water activity of the dough used in the preparation of extruded meat sticks (Table 2). The mean values of moisture content and water activity exhibited an increasing trend with increasing levels of CH and CL. The T3 formulation, containing 4% CH and 4% CL, yielded the highest values for both parameters, whereas the control sample (C), formulated without CH and CL incorporation, exhibited the lowest values. The increase in moisture content and water activity of the raw dough could be attributed to the higher moisture levels of CH (75.02%) and CL (71.76%), which replaced refined wheat flour with a comparatively lower moisture content (9.51%). The cooking yield recorded an increased value with increasing levels of CH and CL incorporation. Similarly, cooking loss was observed to decrease with increasing levels of CH and CL incorporation. The cooking yield of the T3 sample was recorded as the highest and significantly higher ($p<0.05$) than the control sticks. The cooking yield of all the treated samples was recorded as comparable. The higher cooking yield observed in the treated extruded meat sticks could be attributed to the greater water retention resulting from the incorporation of minced CH and CL. Umaraw *et al.* (2021) also reported an increase in the baking yield of breads incorporating chicken meat powder, attributing it to the higher moisture retention in the developed breads. Similarly, Kumar *et al.* (2020) reported an increase in cooking yield and a decrease in cooking loss due to higher moisture retention in the chevon patties.

Extruded Stick

The pH of the developed extruded sticks exhibited a progressive increase with the incremental incorporation of minced CH and CL. A significant ($p<0.05$) rise in pH was observed among the treatments (C < T1 < T2 < T3), corresponding to the higher inclusion levels of minced CH and CL. This increase could be attributed to the inherently higher pH values of the incorporated CH (6.33 ± 0.28) and CL (6.72 ± 0.11). El-Sayed *et al.* (2018) reported that the pH value of gizzard and liver sausages increased with the rising substitution levels of defatted wheat germ.

An increasing trend in water activity and moisture content was observed with the progressive incorporation of minced CH and CL in the developed products (Table 2). The water activity and moisture content of the T3 stick were significantly higher ($p<0.05$) than those of the control. The water activity of C, T1, and T2 samples was recorded as comparable. The improvement in the water activity values of the treated sticks could be attributed to the higher moisture retention in the developed sticks incorporated with CH and CL. The moisture content of T3 was noted to have a significant ($p<0.05$) increase as compared to C and T1. The inclusion of chicken liver has been reported to result in higher moisture content in chicken liver–based pâté, as observed by Porto-Fett *et al.* (2019).

Table 2: Physico-chemical and proximate composition of extruded sticks incorporated with different levels of chicken heart and liver byproducts

Parameter	Control	T1	T2	T3
Raw Dough				
Moisture (%)	32.87±0.29^{a}	34.90±0.08^{b}	34.41±0.02^{b}	36.35±0.14^{c}
Water activity	0.78±0.00^{a}	0.81±0.00^{b}	0.81±0.00^{b}	0.81±0.00^{b}
Cooking yield (%)	63.00±0.81^{a}	64.26±1.07^{ab}	65.61±1.03^{ab}	66.00±0.71^{b}
Cooking loss (%)	37.00±0.81^{b}	35.73±1.07^{ab}	34.38±1.03^{ab}	34.00±0.71^{a}
Extruded Sticks				
pH	5.35±0.01^{a}	5.52±0.01^{b}	5.61±0.02^{c}	5.74±0.01^{d}
Water activity	0.53±0.01^{a}	0.55±0.01^{a}	0.56±0.01^{ab}	0.59±0.02^{b}
Moisture (%)	5.53±0.12^{a}	6.47±0.09^{a}	6.81±0.05^{ab}	7.93±0.82^{b}
Protein (%)	11.10±0.04^{a}	11.22±0.01^{a}	12.39±0.08^{b}	12.47±0.05^{b}
Fat (%)	8.25±0.02^{a}	8.95±0.15^{b}	9.40±0.04^{c}	9.60±0.08^{c}
Ash (%)	2.60±0.04^{a}	2.82±0.03^{b}	3.15±0.06^{c}	3.55±0.02^{d}
Fiber (%)	2.76±0.06^{b}	2.58±0.07^{a}	2.53±0.09^{a}	2.48±0.04^{a}

** Means with different superscripts differ significantly (P<0.05) in a row; n = 6 for each treatment; C- control without chicken heart and liver, T1-extruded sticks with 2% minced chicken heart + 2% minced chicken liver, T2-extruded sticks with 3% minced chicken heart + 3% minced chicken liver, T3- extruded sticks with 4% minced chicken heart + 4% minced chicken liver*

The incorporation of minced CH and CL led to an improvement in the protein, fat, and ash content of the developed extruded sticks. The treated formulations demonstrated significantly ($p < 0.05$) elevated protein and fat contents compared to those of the control samples, with the T3 treatment showing the highest values. In addition, the ash content increased significantly ($p<0.05$) in all enriched samples, reflecting an enhancement in the overall mineral composition of the products. El-Sayed *et al.* (2018) reported that the addition of chicken liver to sausages increased the overall protein content from 34.6 - 37.9%. Similarly, Mehmood *et al.* (2024) reported that chicken nuggets incorporated with beef and chicken liver exhibited higher ash, fat, and protein contents. The incorporation of minced CH and CL influenced the crude fibre content of the developed sticks. A significant reduction in crude fibre ($p < 0.05$) was observed with increasing levels of CH and CL incorporation; however, the differences among the treated formulations were not statistically significant ($p > 0.05$). This effect could be attributed to the replacement of fibre-rich flour components with protein and fat-rich CH and CL.

Instrumental Colour Profile

Minced Heart and Liver

The chicken heart paste exhibited a lightness (*L**) value of 31.08 ± 0.46, redness (*a**) value of 9.64 ± 1.18, and yellowness (*b**) value of 12.54 ± 1.46. The chicken liver paste appeared darker in colour, exhibiting a lightness (*L**) value of 26.84 ± 0.52, redness (*a**) value of 11.43 ± 1.04, and yellowness (*b**) value of 10.72 ± 1.22.

Raw Dough Colour

The incorporation of minced CH and CL significantly influenced various colour quality attributes of the raw dough (Table 3). The lightness (*L**) value exhibited a decreasing trend with increasing levels of CH and CL incorporation, with the T3 formulation exhibiting the lowest lightness value. This reduction in *L** could be attributed to the lower lightness values of CH and CL used in the formulation. The control dough exhibited the lowest redness (*a**) value, showing significantly ($p < 0.05$) lower redness scores compared to the treated dough samples. The more pronounced reddish appearance of the treated dough could be attributed to the higher redness (*a**) values of the incorporated CH and CL. The highest redness (*a**) value was observed in the T3 dough formulation. This could be attributed to the inherent red colour of the minced CH and CL due to the high content of myoglobin. The lowering in yellowness (*b**) values noted in the treated products could be attributed to a colour shift toward a more pronounced greenish hue. The T3 dough sample exhibited significantly ($p < 0.05$) lower yellowness (*b**) value compared to the control dough. A significant ($p < 0.05$) increase in chroma values was recorded in treated dough samples incorporating CL and CH, reflecting improved colour saturation and brightness compared to the control samples. In contrast, the hue angle values declined from 82.31° in the control to a range of 80.15–75.72° in the treated samples, indicating a transition of colour characteristics from yellowish to reddish tones with increased levels of CH and CL incorporation.

Extruded Sticks

Cooking the extruded sticks resulted in a marked change in their colour attributes (Table 3). The lightness (*L**) values of all samples decreased after cooking compared to their respective raw doughs, with the control sample exhibiting the highest and significantly ($p < 0.05$) greater lightness compared to the treated products.

Table 3: Colour variables of extruded sticks incorporated with different levels of chicken heart and liver byproducts

Parameter	Control	T1	T2	T3
Raw Dough				
*L**	41.73 ± 0.22^{c}	40.38 ± 0.59^{bc}	39.40 ± 0.39^{ab}	37.67 ± 1.08^{a}
*a**	2.34 ± 0.12^{a}	3.04 ± 0.10^{b}	3.33 ± 0.20^{b}	4.31 ± 0.18^{c}
*b**	17.55 ± 0.30^{b}	17.40 ± 0.29^{b}	16.92 ± 0.11^{b}	15.75 ± 0.50^{a}
Chroma	16.10 ± 0.53^{a}	17.46 ± 0.13^{b}	17.55 ± 0.28^{b}	17.82 ± 0.30^{b}
Hue	82.31 ± 0.43^{d}	80.15 ± 0.28^{c}	78.09 ± 0.46^{b}	75.72 ± 0.56^{a}
Extruded Sticks				
*L**	30.30 ± 0.24^{a}	27.41 ± 0.81^{b}	26.53 ± 0.41^{b}	26.72 ± 0.91^{b}
*a**	2.82 ± 0.11^{a}	3.14 ± 0.20^{a}	3.20 ± 0.35^{a}	3.24 ± 0.17^{a}
*b**	15.46 ± 0.28^{b}	12.94 ± 0.42^{a}	12.81 ± 0.19^{a}	12.40 ± 0.61^{a}
Chroma	15.72 ± 0.26^{b}	13.34 ± 0.48^{a}	13.22 ± 0.19^{a}	12.80 ± 0.60^{a}
Hue	79.61 ± 0.56^{b}	76.28 ± 1.17^{a}	75.78 ± 0.75^{a}	75.65 ± 0.97^{a}

** Means with different superscripts differ significantly (P<0.05) in a row; n = 6 for each treatment; C- control without chicken heart and liver, T1-extruded sticks with 2% minced chicken heart + 2% minced chicken liver, T2-extruded sticks with 3% minced chicken heart + 3% minced chicken liver, T3- extruded sticks with 4% minced chicken heart + 4% minced chicken liver*

An increase in the proportion of minced CH and CL in the formulation progressively darkened the appearance of the product, as reflected by the significant decline in lightness (*L**) values. The decrease in lightness could be due to colour development from heat-induced reactions, such as non-enzymatic browning and the breakdown of muscle pigments during cooking. A similar reduction in the lightness score of the product was observed upon cooking by Oliveira *et al.* (2015) in pasta preparations and Patil *et al.* (2025) in spent hen meat biscuit preparations incorporating chia seeds. The treated formulations exhibited this effect more prominently, which could be associated with increased protein concentration, facilitating greater participation in Maillard reactions during cooking. The redness (a*) value exhibited a slight increase with the progressive incorporation of minced CH and CL; however, the variation was not statistically significant. This observation could be attributed to the thermal degradation of heat-labile pigments, particularly those responsible for imparting reddish colouration. A similar increase in the redness value was also reported by Kamal *et al.* (2025). Among all the samples, the control sticks exhibited the highest yellowness (b*) values, which were significantly ($p < 0.05$) higher than those recorded for the treated formulations. This trend may be attributed to the combined effects of non-enzymatic browning reactions, starch gelatinisation, and the distribution of fat within the matrix. The reduced chroma values observed in the cooked samples suggest a duller appearance and decreased colour saturation. However, the hue angle remained significantly ($p<0.05$) lower in the treated products (~76.28–75.65°) compared with the control (79.61°), indicating a pronounced shift toward reddish-brown colouration.

Sensory Analysis

The incorporation of minced CH and CL markedly affected the sensory quality parameters of the extruded sticks (Table 4). As the proportion of CH and CL increased, the appearance scores showed a significant decline ($p < 0.05$) at T3 levels. The appearance scores for C, T1, and T2 were recorded as comparable. The reduction in visual appeal may be attributed to the darker hue developed in the product as a result of incorporating these edible byproducts, as indicated by the reduced L* value in Table 3. The control sticks received the highest flavour scores, whereas the T3 formulation recorded the lowest. The flavour ratings of the control and T1 samples, as well as those of T1 and T2, were comparable and showed no statistically significant differences ($p>0.05$). A marked improvement in juiciness was observed in the T3 formulation, which recorded significantly higher scores ($p < 0.05$) than the control. However, the juiciness values of T1 and T2 did not differ considerably from one another. The tenderness evaluation revealed no notable variations between the control and treated samples, indicating that the incorporation of minced chicken heart and liver had minimal influence on this attribute. The overall acceptability of the T2 sticks was recorded as the highest and significantly higher than that of the control and other treated sticks. The scores for the control and T3 samples were comparable, with the T3 formulation exhibiting the lowest overall acceptability among the treatments.

The panelists noted a very prominent flavour of minced CH and CL in T3 sticks. The panelists preferred the flavour of T2 sticks (with 3% minced CH and CL incorporation). Similar to our study, Deepika *et al.* (2022) also reported improvements in the sensory attributes of extruded products incorporating shrimp head exudate and fish flour. An improvement in the sensory characteristics and overall acceptability of the biscuits was also reported upon incorporation of meat by Kumar *et al.* (2021) and Kumar *et al.* (2016).

Table 4: Sensory attributes of extruded sticks incorporated with different levels of chicken heart and liver byproducts

Parameter	Control	T1	T2	T3
Appearance and colour	7.31 ± 0.06^{b}	7.21 ± 0.06^{b}	7.16 ± 0.03^{ab}	7.01 ± 0.04^{a}
Flavour	7.30 ± 0.07^{c}	7.25 ± 0.05^{bc}	7.07 ± 0.04^{ab}	7.00 ± 0.07^{a}
Juiciness	7.02 ± 0.11^{a}	7.15 ± 0.04^{ab}	7.31 ± 0.04^{b}	7.20 ± 0.05^{ab}
Tenderness	7.17 ± 0.08	7.22 ± 0.07	7.20 ± 0.08	7.34 ± 0.12
Overall acceptability	7.07 ± 0.03^{a}	7.25 ± 0.04^{b}	7.45 ± 0.04^{c}	6.99 ± 0.00^{a}

** Means with different superscripts differ significantly (P<0.05) in a row; n = 6 for each treatment; C- control without chicken heart and liver, T1-extruded sticks with 2% minced chicken heart + 2% minced chicken liver, T2-extruded sticks with 3% minced chicken heart + 3% minced chicken liver, T3- extruded sticks with 4% minced chicken heart + 4% minced chicken liver.*

Conclusion

Minced chicken heart (CH) and liver (CL) served as valuable functional ingredients for the development of nutritionally enriched extruded sticks. Their incorporation led to notable improvements in protein, fat, ash, and pH values. However, increasing levels of CH and CL resulted in a darker appearance of the product. The extruded sticks prepared with 3% CH and 3% CL achieved the highest overall acceptability by the sensory panellists. Thus, good-quality extruded sticks with improved nutritive and functional attributes could be produced by the incorporation of 3% chicken heart and 3% chicken liver.

Contribution by Authors

All the authors contributed equally to writing the manuscript. The final manuscript was read by all authors and consented to publication.

Conflict of Interests

There is no conflict of interest.

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