Research Article

Journal of Meat Science
Year 2026, Vol.21 (2)

Functional Enhancement of Extruded Stick by Incorporating Chicken Heart

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Submission: 28 October 2025 **Acceptance:** 3 June 2026

DOI: https://doi.org/10.48165/jms.2026.21.02.03

ABSTRACT

Chicken heart (CH) was incorporated into refined wheat- and rice-flour-based extruded stick formulations to enhance nutritional quality and develop a healthy snack. CH replaced the base flours at 3%, 4.5%, and 6% levels, producing four variants: C (control, without CH), T1 (3% CH), T2 (4.5% CH), and T3 (6% CH). The oven-cooked sticks were evaluated for physicochemical, proximate, colour, and sensory attributes. Increasing CH levels in the formulations resulted in higher pH, water activity, protein, fat, and ash contents, while crude fibre remained comparable. The products darkened with CH incorporation, showing a significant ($p < 0.05$) reduction in lightness (L*) value. The yellowness (b*) score of T1 was significantly ($p < 0.05$) higher than that of the control and other treatments, and the hue angle of treated products (~72–75°) was significantly ($p<0.05$) higher than the control (56.18°). All treated sticks, except T3, exhibited improved tenderness compared to the control sticks. Sensory evaluation revealed that the 4.5% CH formulation (T2) received the highest overall acceptability. Hence, good-quality, protein-enriched extruded sticks can be successfully developed by incorporating 4.5% CH.

Keywords: Chicken heart; extrusion; sticks; quality attributes

INTRODUCTION

Globally, consumption of poultry meat has steadily risen and, in 2022, overtaken pork as the most consumed meat. The poultry sector is very crucial due to its contribution to human nutrition, food security, and economy in India (Hari Raja et al. 2026; Kumar et al. 2026). During poultry processing, a variety of byproducts are produced at each step (Ungureanu et al. 2023). Most of these byproducts are inefficiently converted into low-value products like animal feed and fertilizers, or even disposed of in landfills, posing serious environmental and sustainability concerns (Umaraw et al. 2026). The chicken heart weighs about 0.6±0.18% of the carcass (Karthika et al. 2019). Chicken heart is a good source of micronutrients and protein and provides 153 calories and up to 25.6 grams of protein per 100 grams (USDA Food Data Central 2025). It is a rich source of B complex vitamins, especially Vitamin B_{12} and had a favourable lipid quality with a polyunsaturated-to-saturated acid ratio of more than 0.4 and high levels of minerals such as iron, zinc, and manganese (Seong et al. 2015). Therefore, heart could be selected as a functional ingredient in the preparation of various food products by utilising this undervalued offal.

The chicken heart remains underexploited due to constraints related to consumer perception and technological challenges in its processing and incorporation into value-added products. However, increasing environmental concerns, waste management challenges, and the growing demand for sustainable protein sources have driven efforts to valorize chicken byproducts into high-value ingredients (Shen et al. 2019) by suitable technological interventions such as extrusion.

Extrusion technology offers a practical and versatile approach for transforming these low-cost byproducts into value-added products with desirable functional, sensory, and nutritional properties. Typical extruded snacks available in the market, such as those made from corn, potato, cassava, wheat, and rice, are primarily starch-based (Kumar et al. 2019). Although these products are popular for their texture and palatability, they are rich in digestible carbohydrates with a high glycemic index but lack essential nutrients such as protein, fibre, minerals, vitamins, and phytochemicals (Grasso 2020). There is a growing demand for healthier snacks, which has driven the popularity of extruded products that are low in fat, high in protein, and enriched with natural ingredients. Extruded snacks possess low water activity, which confers extended shelf life and allows storage at ambient temperature (Wang et al. 2022). This characteristic is particularly advantageous when incorporating chicken hearts, which are highly perishable in their fresh state. Through extrusion, the proteins and nutrients in chicken hearts are stabilized. At the same time, microbial growth is minimized, enabling the development of safe, nutrient-enriched, and shelf-stable snack products suitable for broader distribution and consumption.

MATERIALS AND METHODS

Mature spent hens, over 72 weeks old, were obtained from the Directorate of Livestock Farm at Guru Angad Dev Veterinary and Animal Sciences University in Ludhiana, Punjab, India. The birds were humanely slaughtered at the university's experimental slaughter facility, following established guidelines. During processing, giblets, including the liver, heart, and gizzard, were carefully collected, thoroughly cleaned, and sorted into their respective categories. The heart was ground thoroughly, packed in a polyethylene terephthalate (PET) container, and stored in a deep freezer at -18±1°C. The main ingredients used to formulate the extruded stick, such as refined wheat flour, rice flour, spices, refined oil, and salt, were purchased from a local supermarket.

Based on preliminary trials, three minced chicken heart inclusion levels were selected to develop extruded sticks, resulting in four formulations: Control (without CH), T1 (3% CH), T2 (4.5% CH), and T3 (6% CH) (Table 1). The overall preparation procedure for the extruded sticks is outlined in the flow diagram shown in Figure 1.

Mix refined wheat flour, rice flour, salt, spices and refined vegetable oil
↓
Addition of water and minced chicken heart
↓
Grind for 4.5 min to make uniform dough
↓
Remove the dough
↓
Extruded dough on the tray lined with aluminium in stick form
↓
Cooking under hot air oven at 180°C for 15 min with regular turning
↓
Tempering at room temperature
↓
Evaluation, storage and sample analysis

Figure 1. Flowchart for the preparation of extruded sticks incorporated with chicken heart byproduct

Table 1. Formulation for the preparation of extruded sticks incorporated with chicken heart

Ingredients (%)	Control	T1	T2	T3
Refined wheat flour	33.0	31.5	30.75	30.0
Rice flour	33.0	31.5	30.75	30.0
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	-	3.0	4.5	6.0

T1-extruded sticks with 3% minced chicken heart, T2-extruded sticks with 4.5% minced chicken liver, T3-extruded sticks with 6% minced chicken heart

Analytical procedures

The proximate composition of the developed sticks was estimated as per the method described by AOAC (2007). The moisture percent calculated by the Automatic moisture analyzer (AMD MX-50 by Essae®, Japan) by taking 2 g sample heated for 4 min at 105°C. The fat content of extruded sticks was determined using the solvent extraction method (SOCS PLUS SCS 6, Pelican Equipment, India) with petroleum ether (boiling point 60–80 °C), protein content was measured by the Kjeldahl method (Protein = N × 6.25), and ash content was estimated by incinerating the samples in a muffle furnace for 16 h, with temperature increased from 150 to 600 °C in quartz crucibles.

Cooking yield was calculated as the percentage ratio of cooked to raw product weight as following formula-

Cooking yield (%) = [Weight of cooked product / Weight of raw product] x100

The pH of the developed product was analysed by homogenizing approximately 1 g of the sample with 10 mL of distilled water using homogenizer. The pH of the sample was measured using a digital pH meter (SAB 5000, LABINDIA, Mumbai), which was pre-calibrated at room temperature with standard buffer solutions of pH 4.0, 7.0, and 9.0.

The colour profile of the developed sticks was evaluated using a Chroma Meter (Konica Minolta, CR-300, Japan), with results expressed as *L** (lightness/darkness), *a** (red/green), and *3** (yellow/blue) values. Calibration of the instrument was performed using the white calibration plate provided. The hue and chroma of the sticks were subsequently calculated using the formulas described by Froehlich et al. (1983) as-

Hue = (tan-1) b*/a*

Chroma value = $(a^{*2}+b^{*2})^{1/2}$

The water activity (a_w) of the developed sticks was determined using a Water Activity Meter (WA 16 DA) following the standard protocol to assess the availability of free water in the product.

The developed sticks were evaluated for sensory attributes by a panel of seven members, comprising postgraduate students and faculty from the department. Panellists rated the products for appearance and colour, flavour, crispiness, texture, and overall acceptability using a 8-point descriptive scale, where 8 represented "extremely desirable" and 1 represented "extremely undesirable" **(ISO 3972:2011, SS-EN ISO 8586:2014).** The samples were served on white melamine plates and coded with random three-digit numbers to ensure blind testing. Potable water was provided to the panellists to rinse their mouths between samples, preventing any residual taste from affecting subsequent evaluations.

The data collected from the study were analyzed and presented as Mean ± Standard Error by using IBM SPSS Statistics-26 software statistical tool (Snedecor and Cochran 1994). The entire experiment was repeated three times, and duplicate samples were taken for the assessment of various parameters (n = 6), except for sensory analysis (n = 21). Analysis of variance and Duncan's multiple range test (DMRT) were determined at a 95% confidence level ($p < 0.05$).

RESULTS AND DISCUSSION

The chicken heart (CH) used in the present study had 74.05±0.51% moisture content, 18.57±0.35% protein, 5.87±0.19% fat and 1.82±0.04% ash content. The composition of the CH depends upon the source and preparation methods (Suychinov et al. 2025). Such as Yessimbekov et al. (2025) reported 75.88% moisture, 16.30% protein, 6.22% fat and 1.60% ash content in fresh chicken heart byproduct. Seong et al. (2015) reported 11-18% protein and 0.8- 4.5% fat in the edible offal's of poultry. This heart had balanced protein and moderate fat levels and provided a good source of lipids.

Raw Dough

The incorporation of minced chicken heart (CH) had affected the moisture levels and water activity of the dough used to prepare extruded meat sticks (Table 2). The mean values of moisture percent and water activity value were observed to follow an increasing trend with the increasing levels of CH, with the T3 dough with 6% CH having the highest values, and the control product (C) without CH had the lowest values for these two parameters. The increasing moisture content and water activity of the raw dough could be attributed to the high moisture content of CH (74.05%), which was used to replace flours having low moisture content. The cooking yield improved slightly from 59.81% (control) to 62.56% (T3), however the differences were not statistically significant ($p>0.05$). The cooking yield also reported an increasing trend ($p>0.05$) with increasing levels of minced CH, following the trend T3>T2>T1>C. The higher water retention in the treated sticks due to the incorporation of minced CH could be attributed to the higher cooking yield of treated extruded meat sticks. This marginal improvement may be due to enhanced structural integrity and reduced cooking loss in treated formulations, suggesting better matrix stability.

Extruded Sticks

The pH of extruded sticks increased with increasing levels of minced CH. The mean pH value of the control was recorded significantly ($p<0.05$) lower than that of the treated products. The pH of T1 and T2 as well as T2 and T3, were recorded as comparable. This could be due to the higher pH (6.31±0.04) of minced CH. The increasing water activity and moisture content were noted to follow a trend with the increase in minced CH. The water activity of the T2 and T3 sticks was significantly higher than that of the control sticks. The increasing water activity of the treated sticks could be due to the higher moisture content in the CH. The moisture content was noted to have a significant ($p<0.05$) increase with the higher levels of minced CH.

Incorporating minced CH increased the protein, fat, and ash content of the developed sticks. The protein and fat contents of treated sticks were significantly ($p<0.05$) higher than those of control samples, with T3 sticks recording the highest protein and fat levels. Similarly, the ash content of the control sample was significantly lower ($p<0.05$) than that of the treated products, thus representing higher mineral levels in fortified formulations. Increased protein and mineral content were also reported in biscuits made with chicken meat and bran (Kumar et al. 2016) and chia seed (Patil et al. 2025). The incorporation of minced CH did not significantly affect the crude fibre content of the developed sticks. In contrast, crude fibre content showed a slight decreasing trend (2.84%

to 2.76%), although the differences were not statistically significant. This dilution could result from higher protein and fat replacement of fibre-containing flour components.

Table 2. Physicochemical and proximate parameters of extruded sticks incorporated with different levels of chicken heart. (Mean ± S.E.)

Parameter	Control	T1	T2	T3
Raw dough				
Moisture (%)	31.67±0.85^{a}	32.21±1.43^{ab}	33.61±0.51^{bc}	35.42±0.83^{c}
Water activity	0.77±0.21^{a}	0.84±0.11^{b}	0.82±0.09^{b}	0.83±0.13^{b}
Cooking yield (%)	59.81±2.25	60.55±2.15	61.27±2.92	62.56±1.87
Extruded Sticks				
pH	5.33±0.08^{a}	5.43±0.04^{b}	5.52±0.03^{bc}	5.58±0.03^{c}
Water activity (a_w)	0.44±0.05^{a}	0.48±0.07^{ab}	0.52±0.04^{b}	0.53±0.07^{b}
Moisture (%)	4.21±0.34^{a}	4.64±0.27^{b}	5.14±0.14^{c}	5.35±0.18^{d}
Protein (%)	9.19±0.21^{a}	9.82±0.34^{ab}	10.12±0.11^{b}	10.65±0.32^{c}
Fat (%)	8.12±0.11^{a}	8.44±0.16^{b}	8.82±0.13^{c}	9.11±0.18^{c}
Ash (%)	2.71±0.08^{a}	3.21±0.04^{b}	3.55±0.08^{bc}	3.69±0.10^{c}
Fiber (%)	2.84±0.01	2.80±0.01	2.78±0.03	2.76±0.02

* Means with different superscripts differ significantly ($p < 0.05$) in a row; n = 6 for each treatment, T1-extruded sticks with 3% minced chicken heart, T2-extruded sticks with 4.5% minced chicken liver, T3- extruded sticks with 6% minced chicken heart

The incorporation of minced CH significantly impacted the various quality attributes of the raw dough (Table 3). Lightness (L*) increased progressively with the incorporation of treatments, with T3 exhibiting the highest lightness value. This increased lightness could be attributed to dilution of cereal pigments and increased light reflectance due to protein and fat-rich ingredient additions. The redness value (a*) for the Control dough exhibited the highest value, and significantly ($p<0.05$) higher redness scores as compared to treated dough samples. The higher reddish appearance of the control dough could be due to oxidation of natural pigments in the basic formulation. The shifting of colour to yellowish could be the reason for the lower redness scores of the treated products. The highest yellowness score was reported for T1 and T3 dough. The treated dough had significantly ($p<0.05$) higher yellowness scores than control dough samples. Chroma values exhibited significantly ($p<0.05$) higher values in treated dough samples, indicating higher colour intensity and visual vividness. Hue angle increased markedly from 50.76° (in control dough) to above 75-77° in all treated dough samples. This could be due to the shift from a red-dominant tone toward a more yellow-dominant colour appearance in the treated dough samples.

The cooking of the extruded sticks resulted in substantial changes in the various colour attributes. The lightness scores of all samples decreased compared to their raw dough samples, with the control sample having the highest and significantly ($p<0.05$) values compared to treated products. Furthermore, as minced chicken heart levels increased, the product became darker, significantly reducing its lightness score. This reduced lightness might be attributed to intense Maillard browning and pigment denaturation at high temperatures during cooking. This effect was more pronounced in treated formulations, possibly due to higher protein levels, resulting in higher protein interactions with reducing sugars. A similar trend of decreasing redness values among the extruded sticks with progressively increasing minced chicken heart was noticed in the study. This could be attributed to the thermal degradation of heat-sensitive pigments, especially those contributing reddish tones. The yellowness value for T1 sticks was significantly ($p<0.05$) higher than that of the control and all other treated samples. The interactions among browning reactions, starch gelatinization, and fat distribution might be the reason for this trend. The lower chroma value of cooked samples in the present study indicates duller appearance and lower saturation levels. However, the hue angle remained significantly higher ($p < 0.05$) in treated products (~72–75°) than in control (56.18°), showing a dominant shift toward yellowish-brown tones.

Table 3. Instrumental colour profile of extruded sticks incorporated with different levels of chicken heart. (Mean ± S.E.)

Parameter	Control	T1	T2	T3
Raw dough				
L*	34.64±1.17^{a}	37.33±0.89^{b}	39.75±1.08^{bc}	40.5±0.73^{c}
a*	8.78±1.43^{c}	3.77±0.29^{a}	3.93±0.61^{ab}	4.28±0.86^{b}
b*	10.75±0.22^{a}	16.75±0.31^{bc}	16.33±0.17^{b}	16.74±0.11^{c}
Chroma	13.88±1.11^{a}	17.17±0.75^{bc}	16.78±1.53^{b}	17.27±1.13^{c}
Hue	50.76±2.21^{a}	77.31±3.45^{b}	76.47±5.21^{b}	75.66±3.76^{b}
Extruded Sticks				
L*	30.84±1.78^{d}	26.54±1.16^{c}	22.65±0.80^{b}	20.72±0.71^{a}
a*	7.11±1.81^{c}	3.25±0.56^{b}	3.25±1.02^{b}	3.04±0.81^{a}
b*	10.08±0.45^{ab}	12.65±0.39^{c}	10.81±0.71^{b}	9.93±0.69^{a}
Chroma	11.55±1.56^{bc}	13.06±1.23^{c}	11.28±1.07^{ab}	10.38±1.33^{a}
Hue	56.18±4.62^{a}	75.59±3.27^{b}	73.27±4.08^{b}	72.97±2.49^{b}

* Means with different superscripts differ significantly ($p <$ 0.05) in a row; n = 6 for each treatment, T1-extruded sticks

with 3% minced chicken heart, T2-extruded sticks with 4.5% minced chicken liver, T3- extruded sticks with 6% minced chicken heart

The incorporation of minced chicken heart had a significant impact on various organoleptic attributes of the developed extruded sticks (Table 4). The increasing levels of minced chicken heart incorporation resulted in lower appearance scores, with a significant ($p<0.05$) fall in appearance scores with the increasing levels of minced chicken heart. This could be attributed to the increased dark colour of the product due to the incorporation of minced chicken heart. The appearance and colour of the developed extruded sticks in the present study were in accordance with the instrumental colour profile of these sticks presented in Table 3.

The flavour of the Control stick was rated the highest, and the T3 sticks were rated the lowest; however, the flavour scores of T1 and T2 were recorded as comparable ($p>0.05$). Similarly, the flavour score of the Control and T1 sticks was recorded as comparable. The juiciness scores of the control and treated sticks were noted as comparable and statistically insignificant. The tenderness value of treated sticks, except for T3 sticks, was recorded as higher than that of Control sticks. The overall acceptability of the T1 and T2 sticks was recorded as comparable, with the T3 sticks having the lowest overall acceptability score.

The minced heart flavour was very prominent in T3 sticks. The panelists preferred the flavour up to T2 sticks (with 4.5% minced chicken heart 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 attributes 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 analysis of extruded sticks incorporated with different levels of chicken heart. (Mean ± S.E.)

Parameter	Control	T1	T2	T3
Appearance and colour	7.35 ± 0.04^{c}	7.17 ± 0.03^{b}	7.11 ± 0.03^{b}	6.94 ± 0.02^{a}
Flavour	7.36 ± 0.04^{c}	7.22 ± 0.06^{bc}	7.19±0.04b	6.95 ± 0.0^{6a}
Juiciness	7.19±0.04	7.21±0.04	7.28±0.07	7.20±0.04
Tenderness	7.19 ± 0.07^{ab}	7.30 ± 0.06^{b}	7.27 ± 0.06^{ab}	7.11 ± 0.04^{a}
Overall acceptability	7.16 ± 0.07^{b}	7.29 ± 0.05^{bc}	7.32 ± 0.04^{c}	6.98 ± 0.02^{a}

* Means with different superscripts differ significantly ($p < 0.05$) in a row; n = 6 for each treatment, T1-extruded sticks with 3% minced chicken heart, T2-extruded sticks with 4.5% minced chicken liver, T3- extruded sticks with 6% minced chicken heart

CONCLUSIONS

Chicken heart (CH) proved to be a valuable ingredient for the development of nutritionally enriched extruded sticks. Its incorporation enhanced the protein, fat, ash, and pH values of the product. Increasing CH levels darkened the product colour, reflected by reduced lightness and higher hue angle values. Among the tested formulations, the 4.5% CH incorporation provided the best combination of nutritional quality, texture and sensory acceptability. Therefore, CH at a 4.5% inclusion level can be recommended for producing high-quality, protein-enriched extruded snacks with improved functional and sensory properties.

COMPETING INTEREST

The authors do not have any competing interests among themselves or others related to this research work.

ETHICAL STATEMENT

Not applicable

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How to Cite this Article: K A., Kumar P., Mehta N., Sharma A., Sharma R.. (2026). Functional Enhancement of Extruded Stick by Incorporating Chicken Heart. *J. Meat Sci.*, ***21***(2), 16-21. https://doi.org/10.48165/jms.2026.21.02.03