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Optimization of poultry offal and extender levels for cost-effective chicken sausage production

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ABSTRACT

The research was carried out to examine the use of consumable broiler and spent hen offal in raw chicken meat to prepare chicken meat sausages. For preparing chicken meat sausages, along with edible poultry parts such as skin, liver, gizzard, and heart were used at 15%, 20% and 25% levels whereas extenders used at 25%, 30% and 35% respectively. These sausages were tested for quality and sensory characteristics. The chicken meat sausages with 15% consumable offal and 25% extenders had demonstrated significantly ($p<0.05$) greater folding test value, lower frying loss, acceptable pH and shrinkage value, higher cooking yield, and acceptable mean sensory taste ratings compared to the recipes that included edible offal at 20% and 25% and extenders at 30% and 35% respectively. The chicken meat sausages formulated with any of these offal and extenders levels were acceptable in terms of sensory qualities. However, the sausages with 15% edible offal and 25% extenders had better physicochemical and sensory attributes than other formulations. The study shows, the use of offal and extenders not only improves organoleptic, physicochemical and sensory values but also presents immense opportunity for cost reduction in poultry meat processing.

Introduction

The socio-economic structure of Bangladesh, poultry meat is more affordable than other meats, free from social taboos and religious regulations, and widely used to create convenient meat products. Although fresh chicken for household cooking dominates the Bangladeshi market, consumer preference for processed products is rising rapidly for the last few years (Rahman et al., 2021). Globally, ensuring food and nutritional security has become a critical challenge due to the massive growth in population. This necessitates innovative approaches to provide affordable, high-quality protein. Meat and meat products, which are staples in many dietary cultures, play a crucial role in this context (Ursachi et al., 2020). In Bangladesh, whatever the demand is, only 1% of animal meat is processed into branded forms, indicating a slow development rate in the processed meat industry (Rahman et al., 2021). However, the low efficiency in developing meat products is a major concern for sustainable food production (Pintado et al., 2020). Chicken meat, particularly from broilers aged 6-7 weeks, contains little fat but is high in protein. However, the meat from spent hens aged 72-80 weeks is higher in fat but also

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protein-dense, though it tends to be tougher with less favorable functional properties. This tougher meat can be effectively utilized by combining it with broiler meat, offal, and extenders to produce comminuted processed meat products. Chicken meat, being high in quality protein and low in saturated fat, is recommended for all age groups (Bell et al., 2002). Studies show that, consumer preference for broiler meat is influenced by factors such as meat color, odor, fattening system, and handling practices (Gosai, 2021). Sausages, a popular processed meat product worldwide, are produced using various formulations and processes. Various researchers have explored the utilization of spent hen and broiler meat to create value-added emulsion-based convenience products like sausages, patties, and kebabs (Indumathi et al., 2015; Reddy et al., 2017; Bhaskar et al., 2019; Argel et al., 2020). However, the high cost of such products makes them less accessible to lower- and middle-income groups in Bangladesh. Cost-effective meat products are designed to be convenient for consumers, reducing preparation time and utilizing less expensive ingredients like plant-based binders and extenders (e.g., pulses, cereals, and tubers). Such formulations not only improve nutritional, cooking and sensory qualities but also lower production costs (Reddy et al., 2017; Pintado et al., 2020). Notably, about 10-13% of live poultry weight is wasted during slaughter, including byproducts like skin, gizzards, and hearts, which possess comparable nutritional value to lean meat (Bhaskar, 2019). These byproducts, rich in protein and polyunsaturated fatty acids, can be incorporated into processed products for a low-calorie, high-protein diet. This study initiates systematic approach to standardize procedures for producing value-added poultry meat sausages using offal, extenders, or a combination of both. This approach is aimed to develop an optimal formulation that maximizes organoleptic, physicochemical and sensory values while minimizing cost, addressing both consumer needs and sustainability concerns.

Materials and methods

Materials

Broiler chickens and spent hens, aged of 7 weeks and 75 weeks, were sourced from the local market in Barishal and slaughtered following the halal method. The meat was manually deboned within an hour of slaughter. Excess fat, skin, tendons, and connective tissues were trimmed off, and the meat was cut off into smaller parts, packaged in zip-lock poly bags, chilled for 10 to12 hours at 4±1°C, and then frozen at -18±1°C until use in the experiment. Fresh edible poultry by-products, including skin, fat, heart, and gizzard, were obtained from a local meat shop in Barishal. The heart was sliced open lengthwise to remove any clotted blood. Similarly, the skin and fat were thoroughly cleaned, packaged separately in zip-lock poly bags, and stored in a deep freezer at -18±1°C until use in the experiment. The spice mix was prepared using high-quality spices those were first cleaned and dried in a hot air oven at 60±1°C for one hour. The dried spices were then ground using a grinder with an appropriate blade and sieved through a fine mesh to ensure a uniform texture.

Preparation of sausage

The sausage samples were produced at the Animal Products and By-products Laboratory, Patuakhali Science and Technology University, Bangladesh. Before use, iced chickens were thawed at 4±1°C for 16 hours. Any excess noticeable fat and connective tissue were trimmed off, and the lean meat was cut off into cubes and minced twice using a laboratory grinder (Model 82-Classic, Dadaux SAS Co., France) with 6-10 mm steel plates. The sausage formulation followed the method of Syuhairah et al. (2016) with some alterations (Table 1).

To prepare the sausages, the minced chicken was put in a bowl chopper (Model R-10, Robot Coupe, France), and dry ingredients including salt, corn starch, fresh egg white, sodium tripolyphosphate (STPP), wheat flour, oil, and spices were gradually incorporated. Ice water was continuously added at the time of chopping to regulate the temperature. The entire mixing process lasted 10 minutes, ensuring the final batter temperature remained below 12°C. The mixture was then manually stuffed into cellulose casings (2.5 cm in diameter). One batch remained uncooked, while another was steamed using a steamer (Electric and Steamer, Model RS-6, 0881, China) until the core temperature attained at 75±1°C, monitored with a thermocouple probe. The sausages were held at this temperature for almost 30 minutes. After steaming, they were rapidly cooled down by dipping in ice water for 15 minutes, peeled from their casing, vacuum-packed, and refrigerated overnight at 4°C. Each sausage variant was made in two separate batches, with three sausages from each batch designated for further analysis. The prepared samples were labeled and preserved in a freezer at -18±1°C until investigation.

Folding test

The folding test followed a rating scale with five-points grading scheme as described by Cardoso et al. (2008). Chicken meat sausages were cut into slices, each 3 mm thick and carefully bent in half to assess their breakage. The grading criteria were: (1) breaks under slight tactile force, (2) cracks instantly when bent in half, (3) develops cracks gradually when bent in half, (4) remains intact with no visible cracks upon when folding in half, and (5) stays unbroken even after being folded twice.

Frying loss

Sausage slices, each cut to a thickness of 1 (one) cm and deep-fried in soybean oil for 2 (two) minutes and then allowed to cool to ambient temperature. The frying loss was determined by measuring the weight of the slices pre- and post-frying and was expressed as a percentage (Hwang et al., 2011).

$$\text{Frying loss (\%)} = \frac{\text{Weight the slices before frying} - \text{Weight the slices after frying}}{\text{Weight the slices before frying}} \times 100\%$$

pH and shrinkage

Each sample, weighing ten grams, was precisely weighed and blended by adding 90 ml of distilled water for five minutes to ensure uniform consistency. The pH of the ready mixture was then assessed by means of a pH meter (Model HI 84530, Hanna Instruments Co., USA). Additionally, the impact of the cooking process on sausage shrinkage was evaluated by measuring changes in diameter after cooking on an induction cooker and calculated as follows:

$$\text{Shrinkage (\%)} = \frac{\text{Diameter before cooking} - \text{Diameter after cooking}}{\text{Diameter before cooking}} \times 100\%$$

Table 1: Formulations of chicken meat sausages substituted with offal and extenders

Ingredients	Samples/100 g			
	Control (T_0)	T_1	T_2	T_3
Broiler meat	75	40	35	30
Spent hen meat	-	20	15	10
Offal	-	15	20	25
Extenders				
Fresh egg white	3.0	3.0	4.0	5.0
Wheat flour	10.0	10.0	11.5	13.0
Spices	3.35	3.35	3.35	3.35
Starch	1.0	1.0	2.5	4.0
Salt	1.7	1.7	1.7	1.7
Soybean oil	1.8	1.8	1.8	1.8
Sugar	1.0	1.0	2.0	3.0
Ice water	3.0	3.0	3.0	3.0
Sodium tripolyphosphate (STPP)	0.15	0.15	0.15	0.15

T_1; Ratio of offal and extenders: chicken meat = 40:60, T_2; Ratio of offal and extenders: chicken meat = 50:50, T_3; Ratio of offal and extenders: chicken meat = 60:40, offal and extenders used: skin, fat, heart gizzard and fresh egg white, corn starch, wheat flour, sugar respectively at 1:1

Water-holding capacity

The centrifugation method, with slight adjustments, was employed to measure water-holding capacity (Zhuang et al., 2007). A 10-gram sausage sample was mixed with 15 ml of a 0.6 M NaCl solution in a tube, then spun in a centrifuge at 4°C at a speed of 3,000 g for 15 minutes. The water-holding capacity (WHC) is determined as follows:

$$\text{WHC (\%)} = \frac{\text{Weight after centrifuge} - \text{Weight before centrifuge}}{\text{Weight before centrifuge}} \times 100\%$$

Cooking yield

The cooking yield was determined by measuring the sample's weight for each treatment and calculating the weight discrepancy of the sausages before and after being pre-cooked with steam at 75°C for 30 minutes (Choi et al., 2012). It is calculated as follows:

$$\text{Cooking yield (\%)} = \frac{\text{Initial weight of sample} - \text{Final weight of sample}}{\text{Initial weight of sample}} \times 100\%$$

Sensory evaluation

Sensory evaluation of pan-fried chicken meat sausages was carried out using the method described by Rahman et al. (2014), using a 5-point rating system: 5 for excellent, 4 for very good, 3 for good, 2 for fair, and 1 for poor. A panel of ten trained evaluators, including faculty members and postgraduate students (six men and four women, aged 22 to 45), assessed the sausages. The panelists were trained according to AMSA guidelines (1995) at the APT laboratory. Evaluations took place under natural light and at room temperature, with participants providing feedback on color, flavor, tenderness, juiciness, and overall acceptability. All samples were presented in petri dishes.

Statistical analysis

The analysis was performed employing an entirely randomized methodology. In this fully randomized design, five replications of each treatment were included: control (T_0), T_1, T_2, and T_3. Utilizing analysis of variance (ANOVA) (St and Wold, 1989), statistical analysis was conducted. The mean values were assessed through the implementation of the Duncan Multiple Range Test (DMRT) (Tallarida et al., 1987). Statistical analyses were conducted exclusively using RStudio (version 4.2.2) (Allaire, 2012). A significance level of 5% was applied to p-values (two-sided tests) that were equal to or less than 0.05.

Results

Folding test

A significant disparity ($p<0.05$) in the folding test outcomes among the four preparations of sausages is illustrated in Figure 1(a), where treatment three (T_3) received the lowest score of 3.67 and treatment two (T_1) received the second highest score of 4.67. However, the whole meat samples (T_0) exhibited the greatest flexibility, achieving a score of 5.00. There is a downward pattern of folding test scores were observed among the meat-reduced samples.

Frying loss

Figure 1(b) presents the findings on frying loss under deep-frying conditions. The findings from the frying experiment indicate a notable distinction ($p<0.05$) among the interventions, wherein the control group (T_0) incurred the greatest loss (21.33%), imparting a significant reduction of fat and moisture while frying than other samples. A marked reduction (15.67%) was observed in sample (T_3) when meat was largely replaced by extenders and offal. A moderate frying loss (19.00%) was noted in sausages (T_1) formulated with 60% meat, 15% offal and 25% extenders compared to T_2 and T_3 samples sausages.

pH and shrinkage

As presented in Figure 1(c), the use of extenders and offal as meat substitute, the results of the pH test demonstrate a statistically significant ($p<0.05$) distinction among the treatments, with the control (T_0) receiving the lowest value (6.52), and the treatment T_3 sample receiving the highest value (6.67). There is a sharp upward trend of pH level was observed among the meat-reduced samples.

Cooking shrinkage results unequivocally illustrate a distinction ($p<0.05$) among the samples, where treatment T_3 & T_0 indicated the lowest value (4.17%) and highest value (10.33%) respectively [Figure 1(d)]. The shrinkage was 8.33% (T_1) when 60% meat, 15% offal and 25% extenders were added in sausage emulsion and further decreased to 4.17% (T_3) as meat content decreased to 40% and offal and extenders content increased to 25% and 35% respectively. So, a sharp downward pattern of cooking shrinkage percentage was found in the sausage's samples having increased level of offal and extender.

Water-holding capacity (WHC)

The WHC data presents that there is a major variation ($p<0.05$) among the treatments. A comparison of the WHC values (53-61%) across all the samples did not reveal any substantial variations. For WHC treatment T_3 had the lowest value (53.41%) and the control (T_0) receiving the highest value (61.40%) [Figure 1(e)]. As the offal and extender levels increased in the sausage's samples a clear decreasing pattern of WHC observed.

Cooking yield

There is a notable distinction ($p<0.05$) between the treatments in the cooking yield was observed in the current investigation. For the cooking yield the control group (T_0) and treatment T_3 had the highest value (94.48%) and lowest value (89.23%) respectively [Figure 1(f)]. As the offal and extender levels increased along with meat content decreased resulting consistently increased cooking yield percentage of the chicken sausages.

Sensory evaluation

The assessment of sensory perception of various interventions for process optimization is illustrated in Figure 2. There are apparent variations in sensory qualities (color, flavor, tenderness, juiciness, and overall acceptability) across the treatments. The sample T_3, which has a ratio of 60:40 chicken flesh, offal, and extenders (including skin, fat, heart gizzard, fresh egg white, corn starch, wheat flour, and sugar), has the lowest values for these attributes: 3.05 for color, 3.00 for flavor, 3.10 for tenderness, 2.65 for juiciness, and 2.75 for overall acceptability. Also, Panelists gave the control (T_0) sample higher ratings in all categories. However, the extenders and offal incorporated sausages (sample T_1 & T_2) had a more appealing appearance, color, flavor, tenderness and juiciness compared to sample T_0 & T_3, though, the chicken meat sausage (T_0) was rated highest in taste. Incorporating offal and extenders at different levels did not cause any significant (P<0.05) changes in the sensory ratings of chicken meat sausages. The meat-reduced (60% meat and 15% offal) sausages had better color, tenderness and overall acceptability as almost to the score of control samples (T_0). The chicken meat sausage (T_0) which did not contain offal, performed better in terms of sensory attributes.

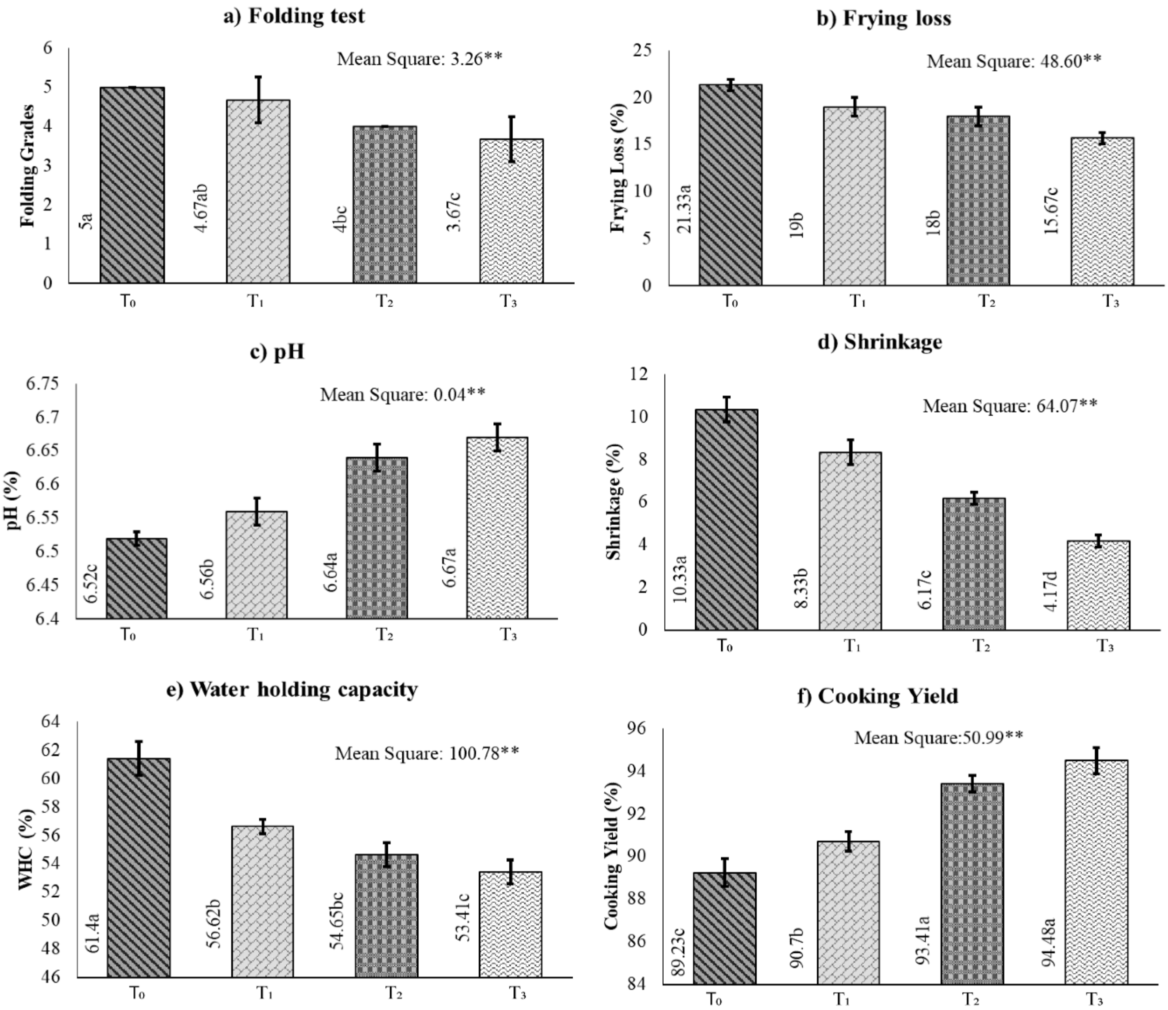

Figure 1: Physiochemical profile of chicken sausage formulation with 25% (T_0) only extender, 40% (T_1), 50% (T_2) and 60% (T_3) offal and extender

Production cost

Considering meat cost, offal and extenders cost, labor, fuel cost, and others (utensil cost) cost it was estimated that the production cost of 1.00 kg chicken sausage was ranges from BDT 219.00 to BDT 290.00 (Table 2).

For calculating the production cost of chicken sausages, control group (T_0) had the highest production cost than the others treatment groups. As the offal and extender levels increased along with lean meat content decreased resulting consistently decreased production cost of chicken sausages.

Table 2: Cost structure of per kg chicken sausage production

Item name	Treatments			
	Control	T_1	T_2	T_3
Boneless broiler meat/kg (BDT)*	240	128	112	96
Boneless spent hen meat/kg (BDT)**	-	90	68	45
Offal (BDT)***	-	11	14	18
Extenders (BDT)	28	28	33	38
Fuel & labor charges (BDT)	17	17	17	17
Utensil & others (BDT)	5	5	5	5
Per kg production cost (BDT)	290	279	249	219

*Boneless broiler meat @ BDT 320/kg ; **Boneless spent hen meat @ BDT 450/kg; ***Poultry offal (skin, fat, heart and gizzard) @ BDT 70/kg ; Market price of 340g (10 pcs) sausage: BDT 260.00

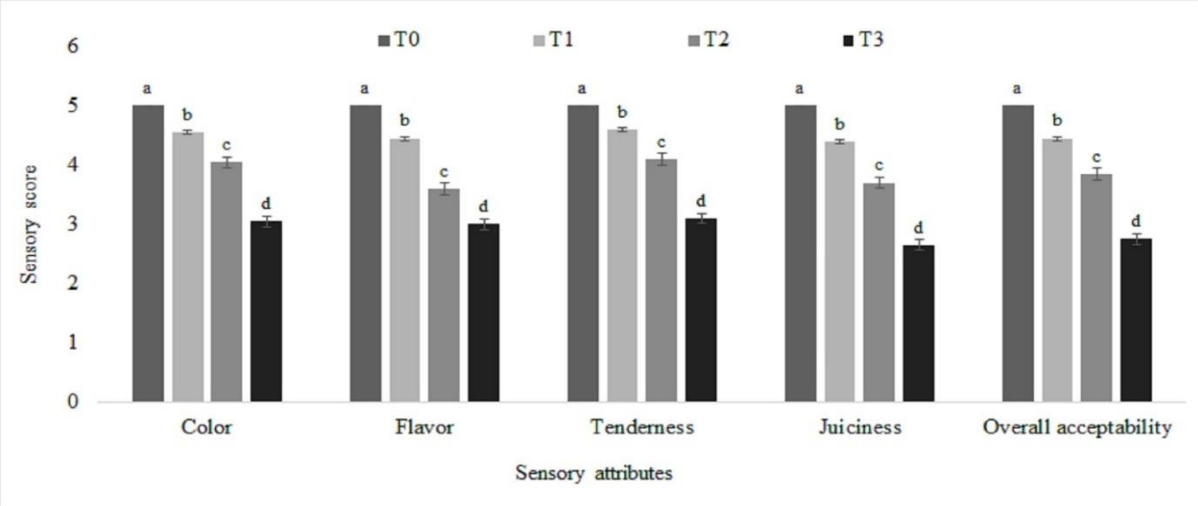

Figure 2: Sensory evaluation of chicken sausage formulation with 25% (T_0) only extender, 40% (T_1), 50% (T_2) and 60% (T_3) offal and extender

Discussion

Folding test

The folding test is a straightforward method used to assess the flexibility, binding quality and texture quality of gel-based composite products, including sausages and meatballs. According to Huda et al. (2009), the folding test scores for commercial chicken sausages ranged from 4.20 to 5.00, which indicates that the folding scores of current studies were in acceptable range. Sausage incorporated with 60% meat, 15% offal and 25% extenders (T_1) demonstrated the highest gel strength compared to the others, following the full-meat samples (T_0). The folding test score serves as a key indicator of meat freshness and the types of ingredients used in sausage formulation. The ability to fold is closely linked to the development of a protein gel network during cooking. In sausage emulsions, myofibrillar proteins from meat and egg proteins (as extenders) play a crucial role in forming this network (Jang et al. 2015). According to the result shown in Figure 1, the sausage mixture with increased level of offal and extenders had a reduced capacity to develop this protein-based network compared to control samples and reducing folding ability in final products, which is align to the findings by Kamani et al. (2019). Thus, it has been demonstrated that using 15%, 20%, and 25% offal, along with 25%, 30%, and 35% extenders in chicken sausage preparation, results in a high-quality product comparable to the control sausage.

Frying loss

The ability of an emulsion to hold onto water, fat, or other components while frying is essential for product quality. Frying loss is influenced by several factors involved in processing, including frying time and temperature, fat content, and the inclusion of specific additives like dietary fibers or isolated proteins within the sausage emulsion (Hwang et al., 2011). For instance, Majzoobi et al. (2017) and Kamani et al. (2019) reported that substituting meat with alternative ingredients led to greater frying loss and reduced water retention, aligning with the results of the current study.

pH and shrinkage

The current study indicates that the incorporation of various levels of extenders and offal affects both the pH levels and moisture retention of the sausages, which are critical for product quality and consumer acceptance. The variations in the pH of the sausages were might because of the initial pH of fresh offal and extenders as well as percentage levels of offal and extenders used in the formulations. On the other hand, the addition of offal, particularly organ meats like liver, may lower pH due to their inherent biochemical composition. In this study, pH values ranged from 6.52 to 6.67, with formulations containing higher percentages of offal and extenders exhibiting slightly acidic profiles. This is consistent with the research by Pintado et al. (2020), who reported that pH variation directly affects sausage emulsion stability and sensory attributes. The findings also align with those of Kim et al. (2016) and Choi et al. (2017) who noted that the pH level of emulsion tends to rise slightly as the amounts of extenders increases.

From the consumer's perspective, cooking shrinkage is seen as a key physical characteristic (Shahiri Tabarestani and Mazaheri Tehrani 2014). Extenders like plant-based ingredients (e.g., pigeon pea flour, corn flour) can replace up to 50% of meat, improving emulsion stability and textural properties (Tahmasebi et al., 2016; Pintado & Delgado-Pando, 2020), which is similar to the results of the current study. Moreover, incorporation of non-meat ingredients in sausages emulsion aimed to minimize shrinkage, thereby improving the final product's yield and quality (Diner et al., 2021), which is also align to current study findings.

Water-holding capacity (WHC)

WHC refers to the ability of meat products, such as sausages, to retain moisture during processing, storage, and cooking. The WHC pattern of the current research might be because a higher level of offal and extender content retain less water, decreasing its water-holding capacity. Sausages made from chicken meat, with 25% non-meat extenders and 15% offal (T_1) showed better water retention ability compared to other sausages. This could be because they formed a more stable meat-protein structure, which resulted in less water and fat being released, thereby improving the binding properties. The findings of this study are consistent with those of Indumathi et al. (2015) in meat balls, Méndez-Zamora et al. (2018) in frankfurters, Fahimeh et al. (2019) in functional sausage and Gosai (2021) in chicken meatballs, who reported that meat emulsions showed slightly higher water-holding capacity when combined with various non-meat ingredients.

Cooking yield

Cooking yield is determined by measuring weight loss due to moisture evaporation, fat loss, and ingredient shrinkage during the cooking process. The cooking yields in the current research were greater than those observed in spent-duck sausages analyzed by Bhattacharyya et al. (2007). However, the findings closely align with those of Muthia et al. (2010) and Reddy et al. (2017), who reported that sausages made with locust bean gum, potato starch, and kappa carrageenan had cooking yields ranging from 96.86% to 97.00%. Meanwhile, the yields in this research were somewhat lower compared to commercial chicken sausages, which Huda et al. (2009) documented at 99.17% to 102.46%.

Sensory evaluation

Sensory attributes play a crucial role in determining consumer preference for sausage products. Since sausages are a processed meat product, their taste, texture, aroma, appearance, and mouthfeel play a crucial role in determining their market success. Sensory analysis helps manufacturers, researchers, and quality control teams ensure consistency and optimize product formulations. The findings of this study align with those of Indumathi et al. (2015) in meatballs, Méndez-Zamora et al. (2018) in frankfurters, Fahimeh et al. (2019) in functional sausages and Gosai (2021) in chicken meat balls, who reported that meat emulsions extended with various non-meat ingredients exhibited moderately acceptable sensory attributes. The sensory evaluation showed that using offal and non-meat extenders and fillers as a substitute for meat in sausages is very appealing based on sensory factors.

Production cost

The price of sausage can be lowered with optimum replacement of lean meat by offal and suitable non-meat extenders without a significant compromise with quality. In the study it was also observed that sausage with poultry by-products extension was cheapest because of higher level of replacement and yield.

Conclusion

This study examined whether offal and non-meat extenders could partially replace chicken meat in sausage production. The results showed that these ingredients enhanced emulsion stability, reduced shrinkage, and minimized cooking and frying losses. Additionally, they maintained an acceptable pH level and received favorable sensory evaluation scores. The sensory analysis indicated that the overall acceptability of the modified sausages was nearly the same as that of traditional full-meat sausages. In summary, the study suggests that using offal and extenders can boost nutritional value and reduce production costs in the meat industry. However, further research is needed to enhance the sensory qualities, which remain the main challenge in producing sausages with reduced meat content.

Authors contribution

Conceptualization, study design, methodology, administration, project management, laboratory activities, data curation, formal statistical analysis, writing, review and editing: MHR; laboratory activities, manuscript writing: AH; formal statistical analysis, manuscript writing and editing: TA; formal statistical analysis, manuscript writing: MI. All authors have read and agreed to the published version of the manuscript.

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Data availability

With the authors' permission, all relevant data used in this study will be made public.

Conflicts of Interest

The authors declare no conflict of interest.

Consent for publication

All the authors agreed and decided to publish this article in the Bangladesh journal of Animal Science.

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