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Physicochemical, Sensory, Chemical Stability and Cost Evaluation of Beef Sausages Produced with Substitution of Fat with Bovine Blood

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Abstract

The purpose of this study was to develop a nutrient-rich and shelf-stable beef sausage by partially replacing animal fat with bovine blood. Fat is a fundamental ingredient in sausage formulation; however, animal fat is increasingly being implicated in ill health worldwide, prompting processors to rethink sausage formulations and explore low-fat alternatives. Various fat substitutes have been tested, with varied results, while bovine blood is widely accepted as a food ingredient in Kenya. A completely randomised design was used with fat-to-blood ratios of 20:0, 15:5, 10:10, 5:15, and 0:20. The sausages were evaluated for sensory properties and analysed for proximate composition, texture, cooking loss, water-holding capacity, iron content, fat oxidation using peroxide value for keeping-quality determination, and cost. One-way ANOVA was used to analyse the data, while Duncan's multiple range test was applied to determine differences among the means. Twenty untrained panellists with familiarity with sausages participated in the sensory evaluation. The findings showed that fat substitution with blood above 10 per cent was not considered acceptable by the panellists. However, substitution significantly increased the protein, iron, and water contents of the sausages ($p < 0.05$), while reducing water-holding capacity and increasing cooking loss. Reducing the fat content of the sausages led to reduced peroxidation, with a 5 per cent fat level yielding a peroxide value as low as 6.4 meq/kg. The study concluded that it is possible to produce an acceptable fresh beef sausage by partially substituting up to 10 per cent of the fat with bovine blood, while also reducing production costs.

Key words: Beef sausage, bovine blood, fat replacer, sensory evaluation, peroxide value.

1.0 INTRODUCTION

The consumption of processed beef sausages is increasing as part of the growing ready-to-eat food market, especially among people living in cities who want easy and protein-filled meals (Data Intelo, 2025). Beef sausages are usually made by cutting beef into pieces and mixing it with fat, salt, spices, binders, water and other things before putting the mix into natural or man-made casings. Even though sausages are liked for being easy, tasty and good for you, they often have a lot of animal fat. Some processed meat items, like frankfurters and bologna, can have as much as 30 per cent fat, and fresh pork sausages can have even more (Cerón-Guevara et al., 2020; Mohammed et al., 2024). So, creating sausage recipes that lower the fat without losing nutrition and taste is still a big challenge for people who make food products.

Fat serves a multifaceted purpose in some meat products, with nutrition being a major factor. Nutrition is a very important factor in food selection (Perez-Cueto & Olsen, 2020). Fat performs three major physiological roles in food, namely supplying essential fatty acids, facilitating the absorption of fat-soluble vitamins, and providing energy (Andrès et al., 2024). In meat products, it is also important in determining flavour, texture, mouthfeel, juiciness, and the lubricating sensation of cooked products. Consequently, reducing fat content may negatively influence the acceptability of sausages (Fernández et al., 2024; Yim et al., 2015). Applied fat alternatives areguided by different targeted outcomes depending on the consumer needs. The needs could bring negative health issues, as those dominating the debate on consumption of animal fat, or they could be related to aesthetics. Proper formulation is critical in finding a balance between achieving fat reduction and retaining the desired properties in the final products.

This is not always easy because, with excessive fat reduction, these products become bland and dry, and the texture can be hard, rubbery or mealy (Zhang et al., 2022). Despite fat serving such a crucial role in meat products, health organisations all over the world have advocated reducing its intake, particularly fats high in saturated fatty acids andcholesterol, as a means of preventing obesity and cardiovascular disease (Clemente-Suárez et al., 2023; Geiker et al., 2021). According to Matsushita et al. (2020), here is also an increased prostate cancer risk with increased intake of food rich in animal fat.

Animal blood has been studied in recent years as a low-cost source of nutrients, especially protein (18 g/100 g) and iron (30 mg/100 g), with functional and sensory properties that are acceptable for human consumption (Chiroque et al., 2023; Ofori & Hsieh, 2014). Blood sausage is rich in high biological value proteins, amino acids, essential fatty acids, and iron (Berisha et al., 2023). The food industry utilises animal muscle meat and other sections of the animal for the manufacturing of a variety of marketable products, such as sausages, hams, and bologna (Gómez et al., 2020), and these products have high levels of fat. For instance, frankfurters and bologna may have as much as 30 per cent fat, and fresh pork sausages may contain up to 50 per cent fat (Cerón-Guevara et al., 2020; Mohammed et al., 2024). Blood, especially in Kenyan slaughterhouses, has not been well utilised either in informal or commercial processing.

Previous studies have shown that animal blood is an ingredient in meat products because it has good protein and iron, and it can add nutrition and taste (Chiroque et al., 2023; Ofori & Hsieh, 2014; Berisha et al., 2023). Most of the research has looked at the nutritional, physical and taste features of products that have blood in them. Not much work has been done on using blood to replace some of the fat in beef sausages. Because of this, the best amount of blood to use and how it affects taste features, how long it stays fresh, how long it lasts on the shelf, and the cost is still not clear. This study therefore looked at how bovine blood can replace some fat in beef sausages. The goal was to find an amount to use that reduces fat but still keeps the product good for nutrition, taste, shelf life and production cost.

2.0 METHODOLOGY

Sausage Formulation and Production

A completely randomised design was used, with the fat: blood ratio as follows: 20:0, 15:5, 10:10, 5:15 and 0:20. Tests were done in triplicate. Table 1 shows the blood and fat replacement model in percentages. A standard sausage production method, referred to as the conventional method, was used as a control. Only the fat content was varied, with other ingredients remaining the same. Silverside steak, abdominal fat, and blood from a mature Borana bull were obtained from a local slaughterhouse in Nairobi immediately after slaughter. Blood collection was done immediately after sticking the animal to prevent contamination, and it was packaged in sterilised polythene bags and transported in cool boxes to a pilot meat processing plant within 2 hours of slaughter. In the pilot plant, the steak was minced using a tabletop mincer with the sieve set at 5mm. The minced meat was apportioned into five batches of approximately 200g each.Other ingredients and spices were bought from an authorised supplier.

The batches contained the standard sausage ingredients and fresh blood at different levels of fat substitution as shown in Table 2. Table 3 shows the additives and seasonings incorporatedin the sausages. Each treatment group was pseudo-replicated three times. The stuffed casingswere twisted at 8 cm intervals for shorter linked units. Figure 1 shows the sausage-making process flow. The sausages were cooked immediately after processing by immersing them in hot oil at 120 degrees Celsius and frying until golden brown.

Table 1: Fat-to-Blood Ratios in Both Grams and Percentages

RUN	BLOOD (%)	QUANTITY(g)	FAT (%)	QUANTITY(g)
1	0	0	20	200
2	5	50	15	150
3	10	100	10	100
4	15	150	5	50
5	20	200	0	0

Table 2: Grams of Ingredients per kg of the Different Fat-to-Blood-Level Sausages

Run	Beef	Blood	Fat	Ice	Wheat Flour	Rusk	Corn Starch	Additives	Seasonings
1	500	0	200	180	60	40	20	19.8	3
2	500	50	150	180	60	40	20	19.8	3
3	500	100	100	180	60	40	20	19.8	3
4	500	150	50	180	60	40	20	19.8	3
5	500	200	0	180	60	40	20	19.8	3
Total	**2500**	**500**	**500**	**900**	**300**	**200**	**200**	**99**	**15**

Table 3: Additives and Seasonings for a 1 kg Sausage Formulation

Additives	Quantity (gm.)	Seasonings	Quantity (gm.)
Common salt	16	White pepper	2
Sodium tripolyphosphate (STTP)	3	Nutmeg	0.3
Ascorbic acid	0.3	Mace ground	0.3
Monosodium glutamate (MSG)	0.5	Coriander & Ginger	0.4
Total	**19.8**	**Total**	**3**

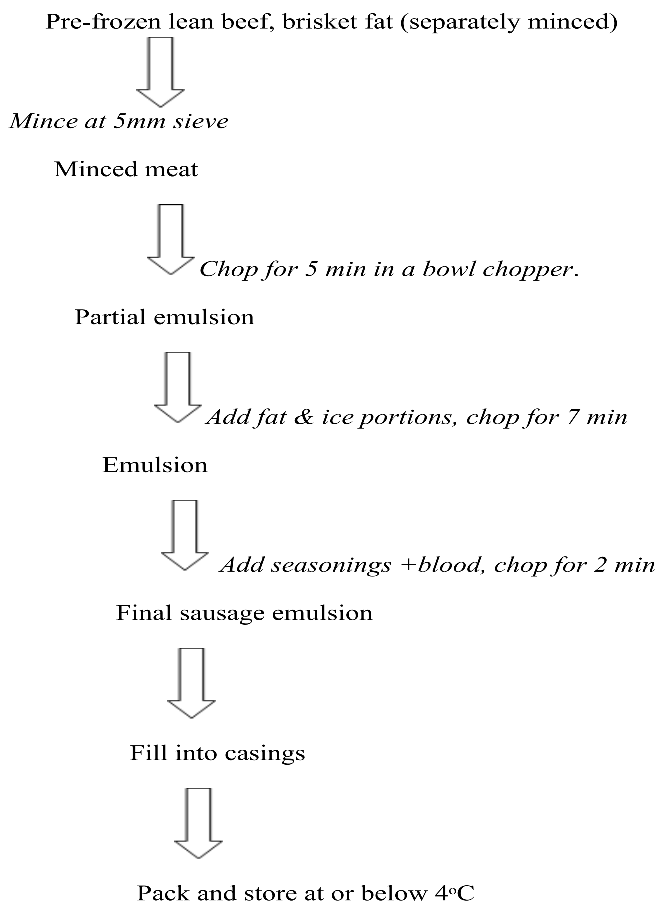

Figure 1: Process Flow Diagram of Sausage Production

Analytical Methods

Sensory Analysis

Eleven panellists were engaged in sensory evaluation. They comprised semi-trained food scientists who are familiar and regular consumers of sausages and whose key focuswas on colour, odour, taste, texture and overall acceptance. Coding was done randomly using three-digit codes to enable subjective, unbiased and independent evaluation among the panellists.The panellists were instructed to finish with all attributes of one sample before proceeding to the next one to aid objectivity. Rinsing water was duly provided for mouth rinsing between samples. The sensory room conditions were similar for all panellists: white lighting, separated stations, similar plate colours and no foreign odour. A five-point hedonic scale was used by the panellist for their judgement: 5 dislike extremely, 4 dislike moderately, 3 neither like nor dislike, 2 like moderately, 1 like extremely, as recommended (Xia et al., 2021).

Proximate Composition

Based on the AOAC (2005) methods, the amount of protein, total ether extract as fat, and moisture content for the sausages were assessed. The moisture content of the samples was measured by oven drying at 105°C in accordance with method 967.08. Crude protein was assessed using the Kjeldahl procedure (988.05), while crude lipid content was determined using Soxhlet extraction (2003.06). The wet iron digestion method was used before being quantified using an atomic absorption spectrophotometer. Analyses were conducted in independent experimental duplicates, and all reagents were of analytical grade.

Cooking Loss

Cooking loss was determined as described by Zhang et al. (2020) by calculating the per cent weight loss during cooking of the sausages in water at 75ºC.

$$\text{Cooking loss} = \frac{\text{weight before cooking- weight after cooking}}{\text{Weight before cooking}}) \times 100$$

Water Holding Capacity

Water-holding capacity was measured using a modified method from Mohammed et al. (2023). Samples of 1.5 g were placed into pre-weighed thimbles consisting of one piece of Whatman no 3 paper folded around two pieces of Whatman No. 50 filter paper. Samples were centrifuged at 1500 × g for 10 minutes, and the filter paper was re-weighed to determinethe total moisture prior to centrifugation. Free moisture was calculated as the weight gained by the filter paper on centrifugation. Water holding capacity was expressed as the percentageof water left on the sample.

Hardness Measurement

The sausages were sliced into equal duplicates of the same thickness (2cm). The casing was removed before analysis, which was done under similar conditions for all samples. Each slice wasplaced in a cross-sectional alignment on the rheometer base plate at a time. A Sun Rheometer Compac-100 (Japan) with a reader CR-1000 (Japan) was used for the hardness measurement in Newtons. It was set to penetrate the slices laterally from the casing side up to a maximum of5mm at a speed of 100mm/min. The measurement on each slice was replicated twice.

Color Measurements

Colour was measured using a Hunter Lab colourimeter in L*a*b* values (Minolta Chroma meter CR-200, Minolta, Inc Japan). Samples were cooked at 90 C for o 5 min and sliced into pieces 4 mm thick (Huda et al., 2000). The colour reading included lightness (L*), redness (a*) and yellowness (b*). The colourimeter was calibrated throughout the study using a standard white ceramic tile.

Chemical Stability Assessment

Chemical stability during storage was assessed by determining the peroxide values on day 0, day seven and day fourteen at 4 degrees Celsius storage. Method Cd 8-53 (AOCS 2003) was used to carry out the tests. This was done to determine the keeping quality of the sausages to establish the appropriate shelf life for the sausages.

Cost Analysis

The cost analysis of the production of the sausages was done by listing the production facets and comparing their current market costs head-to-head for the commercially viable sausage formulations. The breakdown costs considered include: cost of raw materials, ingredients, packaging, transport and labour.

Statistical Data Analysis

The data were analysed using one-way analysis of variance (ANOVA) and Duncan's multiple range test for multiple mean comparisons. The data were processed using Genstat software version 15.0, and significance was defined at $P<0.05$. Sensory analysis descriptive data were analysed using SPSS for Windows version 20, and the differences in means were determined using Duncan's multiple test at $P\leq0.05$.

Approvals And Permissions

The blood was obtained from a public health certified slaughterhouse with source animals approved by local government meat inspectors. Sensory panellists were recruited on a voluntary basis with consent forms signed by all participants.

3.0 RESULTS AND DISCUSSION

Sensory Evaluation

Table 4 shows that sensory acceptability usually declined as fat was increasingly replaced with blood, though sausages with up to 10 per cent blood stayed acceptable. The 5 per cent fat formulation was similar to the full-fat control for most sensory characteristics, suggesting that small fat substitution had little impact on product quality. In comparison, the 10 per cent formulation displayed a more significant decrease, especially in colour ($P<0.05$). The alteration in hue may be linked to the heightened presence of blood pigments alongside the diminished amount of fat, which modifies the visual properties of the sausage. Comparable research has indicated that variations in fat content can affect the colour and sensory attributes of sausages (Ozturk-Kerimoglu et al., 2022; Bureš et al., 2024).

The decrease in flavour and texture with higher blood replacement can be mainly linked to the continuous decrease in fat content. Fat plays a key role in flavour enhancement, juiciness, lubrication, mouthfeel, and appealing texture traits, so its reduction may lead to drier and firmer products. Recent research has indicated that decreasing animal fat in sausages can change texture and sensory properties, yet acceptable products may still be achieved if fat reduction is managed or suitable fat-replacement methods are applied (Li et al., 2023; Vasilev et al., 2023). Odour was relatively unaffected, indicating that moderate blood inclusion did not significantly impair the distinct aroma of the sausages.

In summary, the results indicate that a 5 per cent blood substitute yielded sensory attributes most similar to the full-fat control, whereas 10 per cent signified the highest acceptable degree of fat substitution within the parameters of this study. Despite some decline in the 10 per cent formulation, especially regarding colour, its overall sensory quality stayed acceptable. Blood replacement beyond 10 per cent would likely further diminish appearance, flavour, texture, and overall desirability.

As a result, the 5 per cent blood formulation exhibited sensory traits most similar to the full-fat control, whereas the 10 per cent formulation indicated the highest acceptable quality. Consequently, these two formulations were deemed suitable for further quality attribute evaluations, suggesting that regulated blood replacement might offer a viable method.

Table 4: Sensory Attributes of Sausages

SAMPLE				**ATTRIBUTES**		
FAT (%)	**BLOOD (%)**	COLOR	ODOR	TASTE	TEXTURE	OVERALL ACCEPTABILITY
20	**0**	1.18^{a}	1.27^{a}	1.18^{a}	1.36^{a}	1.18^{a}
15	**5**	1.91^{a}	1.91^{ab}	1.45^{a}	1.73^{a}	1.64^{a}
10	**10**	3.45^{b}	2.82^{bc}	2.82^{b}	2.82^{b}	3.09^{b}
5	**15**	4.18^{b}	2.91^{c}	2.91^{b}	3.09^{b}	3.64^{b}
0	**20**	3.55^{b}	2.36^{c}	2.91^{b}	3.00^{b}	3.64^{b}

Superscripts a, b, c indicate that means along the same row with similar superscripts are not significantly different (P<0.05)

Proximate Composition

Results for proximate composition, which include moisture content, fat, protein and iron contents, are shown in Table 5. The moisture content increased with an increase in replacement ofthe fat with blood, ranging from 62.935 to 64.65 per cent. This, however, did not represent any significant difference for all three sausages at 0 per cent, 5 per cent and 10 per cent fat replacement (P<0.05). The increasing moisture content witnessed in the sausages with increasing blood was as a result of the fact that blood has very high loosely bound water. That water manifested itself in the sausages, which consequently led to a higher cooking loss and low water-holding capacity, as shown in Table 6. These results were in agreement with those reported by Öztürk-Kerimoğlu et al. (2020) and Mohammed et al. (2024), who found higher water content in low-fat sausages.

The protein content increased progressively (14.26% to 15.93%) with the increase in fat replacement with blood, although this did not result in a significant difference among all sausages (P<0.05). The highest protein content value was exhibited at 10 per cent fat replacement (15.93%) replacement with the lowest protein content being in the control sausage at 14.26 per cent. There was aninverse relationship between fat replacement with blood and fat content of the sausages. All the sausages' fat contents were significantly different (P<0.05).

Iron content also increased with the increase in blood in the sausages. This was evidenced by the huge leaps from the control all the way up to the 10 per cent fat replacement. All sausages at 5 per cent, 10 per cent and control showed significant differences (P<0.05). The increase in protein with increasing blood inclusion in sausages can be explained by the high protein content of blood (Gupta et al., 2024). This was also in agreement with earlier studies by Gupta et al., who found blood sausages to be rich in high biological value proteins. The decrease in fat content with increasing blood was clearly due to direct fat removal. Further, the fact that blood does not contain fatty tissue can also explain the decrease in fat content. Blood showed immense potential as a partial fat replacer in sausage, as all sausages were significantly different at P<0.05. This is consequently good for health, as animal fats are high in cholesterol. Obesity, heart disease, and prostate cancer have all been associated with high cholesterol and animal fat intake (Wang et al., 2022; Zeng et al., 2023).

Iron is an essential micronutrient that is very useful for a human body's physiological processes. It plays an integral part in oxygen transport in the body as well as enzyme activities. It is generally recommended that an adult should not take more than 45mg per day. Adult men and women have a recommended daily requirement (RDA) of 8mg and 18mg per day, respectively, according to the Institute of Medicine of the National Academy of Sciences.

One average-sized sausage weighing 50 grams and containing 5 per cent and 10 per cent blood can provide 14.2mg and 28.9mg of iron, respectively. This therefore provides more than both adult men's and women's RDAs, which is consequently a cost-effective nutritional advantage. The highest overall acceptable fat-to-blood substitution sausage, at 10 per cent blood, provides a significantly higher level of iron than the full-fat sausage. Blood is very rich in iron (Gupta et al., 2024). Therefore, it leads to an increase in iron as the blood content in the sausages increases.

Table 5: Proximate Composition of Sausages with Different Levels of Fat Substitution with Blood

FAT LEVEL (%)	20	15	10
BLOOD LEVEL (%)	0	5	10
FAT	25.70 ± 0.6^{a}	23.50 ± 0.62^{b}	22.10 ± 0.3^{c}
CRUDE PROTEIN	14.26 ± 0.76^{a}	15.09 ± 0.22^{ab}	15.93 ± 0.31^{ab}
MOISTURE	62.93 ± 0.28^{a}	62.97 ± 0.86^{a}	64.65 ± 0.71^{ab}
IRON CONTENT (mg/kg)	236.3 ± 2.97^{a}	283.6 ± 1.56^{b}	576.6 ± 1.84^{c}

Superscripts a- b indicate that means along the same row with similar superscripts are notsignificantly different (P<0.05)

Cooking Loss, Water Holding Capacity and Hardness

Results for cooking loss (CL), water holding capacity (WHC) and hardness of the cooked sausages are presented in Table 6. There was an increase in cooking loss (9.44% to 10.71%) with increasing fat replacement with blood. However, the losses were not high enough to make a significant difference (P>0.05) for both 5 per cent and 10 per cent replacement. The cooking loss also increased with the increase in protein content. A decreasing trend was noted for the WHC from the control to the 10 per cent blood inclusion. This too did not represent a significant difference (P>0.05) for allthree sausage samples. There was a general trend of an increasing cooking loss, reducing water-holding capacity and increasing moisture content with the increase of blood. The hardness of the sausages decreased with the reduction in fat content. The control sausage and the5 per cent fat replacement had no significant difference (P>0.05). The highest force required to penetrate the sausages was 0.06N for the full-fat sausage, while the 10 per cent fat replacement required 0.035N. This indicates the strength afforded to the sausages by fat compared with blood as a replacement.

The high cooking loss and low water holding capacity exhibited by the sausages with increasing blood can be attributed to the increase in moisture content in the sausages. Removingfat, which is a good water binder, and replacing it with blood, which is predominantly water, withoutadding more water binders in the sausage formulation led to the availability of more loosely bound water that easily moves off during cooking. The increase in cooking loss with increasing protein content in the sausages can be attributed to the fact that, during cooking, hightemperatures cause protein denaturation that otherwise binds the water through its network (Xia et al., 2021).

Table 6: Physical Properties of Sausages at Different Blood-to-Fat Levels (%)

FAT LEVEL (%)	20	15	10
BLOOD LEVEL (%)	**0**	**5**	**10**
Cooking loss (%)	9.44±0.46[a]	9.73±0.61[a]	10.71±0.48[ab]
Water holding capacity (%)	86.52±0.51[a]	86.16±0.5[a]	85.12±0.66[ab]
Hardness(N)	0.06±0.007[b]	0.06±0.00[b]	0.035±0.007[a]

Superscripts a and b indicate that means along the same row with similar superscripts are not significantly different (P<0.05). N= newtons.

The decreasing water-holding capacity with the reduction in fat further highlights the importanceof fat in a sausage. Fat in meat products can reduce cooking loss and improve water-holding capacity. (Dautova et al., 2024; Mohammed et al., 2024). Increased fat reduction agrees with results in earlier studies that when fat is removed from meat products, high cooking loss and low water-holding capacity are observed (Serdaroglu et al., 2016). Reduction of fatlevel increases the weight losses of sausages (Hu et al., 2022). The decrease in hardnessof the sausages with the increase in blood and moisture content agrees with an earlier study bySerdaroglu, that high moisture content improves the tenderness of a sausage (Atashkar et al., 2018). This further emphasises the importance of fat for the textural hardness of sausages, where excessively low-fat leads to excessively tender products.

Colour Characteristics of the Sausages

Colour measurements were classified as lightness (L*), redness (a*) and yellowness (b*). Thelightness (L*) of the sausages decreased from 66.9 for zero blood to 40.6 for 10 per cent blood inclusion, with the reducing fat content, where all the sausages were significantly different (P<0.05). The redness (a*) of the sausages exhibited an increase with the increase in blood, ranging from 12.7 for full fat to 28.7 for 10 per cent blood levels. They were all significantly different (P<0.05). The yellowness exhibited mixed results for the different fat levels, although the full fat and the 10 per cent blood inclusion showed no significant differences with a 5 per cent fat reduction.

The colour of a product is a fundamental aspect in regard to marketing, branding and acceptability by the consumer. Colour is the single most important factor of meat products thatinfluences consumer buying decisions, as it indicates freshness or otherwise of the product (De Araújo et al., 2022). Colour and product appearance are very important criteria that influenceconsumer patronage (Berthold et al., 2024). Colour represents perceived freshness and is of vital importance to the meat industry and meat science research (Tomasevic et al., 2021).

The decreasing colour ratings with fat reduction can also be attributed to the fact that increasing the fat content in meat products also influences lightness, redness, and yellowness (Mishra et al., 2023). Basically, the reduction of fat level in sausages makes them darkerand redder (Mohammed et al., 2024).

Peroxide Value of the Sausages

The fat peroxidation profile for the sausages is shown in Figure 2. The highest amount, represented as oxygen milliequivalents (meq) per kilogram, was 18.3meq/kg for the full-fat sausage at day 14, with the lowest being 8.5 meq/kg for the full-fat sausages on day 0. All the sausages showed an increasing trend for peroxidation throughout the storage period, but the quantities were reduced with the reduction in fat content of the respective sausages. The 10 per cent fat replacement exhibited the lowest peroxidation with 8 meq/kg, 9.2 meq/kg and 10.3 meq/kg for days 0, 7 and 14 respectively. The lower the fat content, the lower the peroxidation the sausages underwent.

The peroxide value is used to show the extent of spoilage through fat oxidation. Therefore, the higher the fat content, the higher the peroxidation and value. Lipid peroxidation in food is important because it progresses faster in products with higher fat content (Taerian et al., 2024). The peroxide value is low during the beginning of a food's shelf life (Manzocco et al., 2020). The polyunsaturated and unsaturated fatty acids present in the fats usually react with oxygen to form fatty acid hydroperoxides. Hydroperoxides are unstable and break downinto various compounds, which consequently produce off-flavours, leading to a stale, rancid flavour in foods (Geng et al., 2023). Among the sausages, however, the peroxide values were much lower than 25 millequivalent/kg sausage, which is considered the limit of acceptability in fatty foods. According to Seo et al. (2021) the acceptable peroxide values were found to be between 3 and 20 meq/Kg. Fat replacement with blood at both 5 per cent and 10 per cent exhibited very good keeping qualities in sausage, as all the sausages were well below the limits. Sausages with 10 per cent fat replaced with blood had the best storability at less than 20 meq/Kg for 15 days at 4^{o}C, which is the limit above which deterioration of the organoleptic and nutritional characteristics of foodstuffs occurs (Gilbraith et al., 2021).

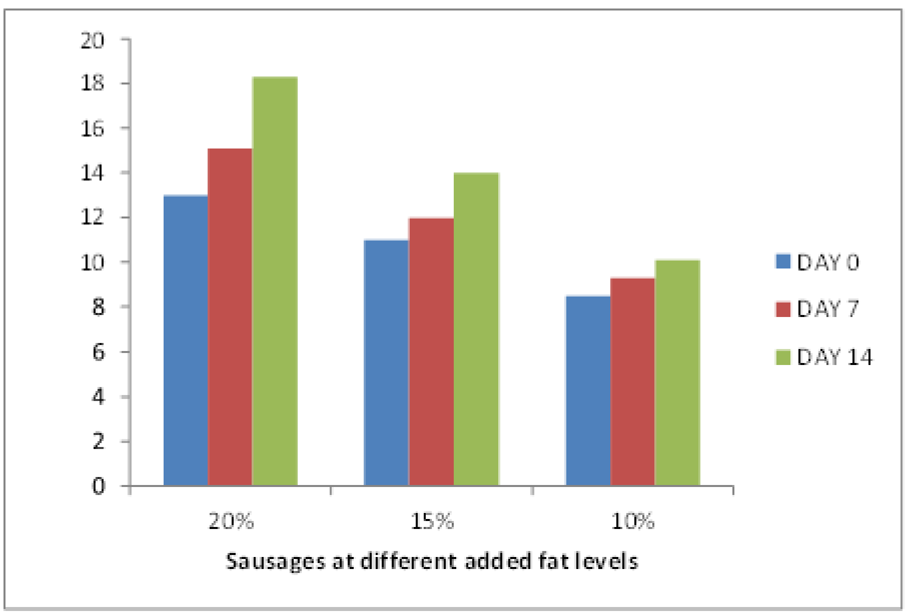

Figure 2: Peroxide Values at Different Storage Periods at 4°C

Cost Benefit Analysis

The comparative production cost for the control, 5 per cent, and 10 per cent blood inclusion showed a cost benefit to the processor (Table 7). Since all the other ingredients and materials were constant, only the Fat cost varied from the control. Blood was obtained for free from the slaughterhouse. That led to reduced cost for sausages whose fat was replaced with blood. The total production cost per kilo for the control was USD 2.810 since it required full fat in its formulation. The 5 per cent and 10 per cent fat replacement cost USD 2.560 and USD 2.435, respectively. That accounts for up to USD 0.375 cost relief per kilo, which translates to a 13.35 per cent cost reduction for blood-enriched sausage production.

The cost benefit analysis clearly showed that it is cheaper for the commercial processors to useblood as a sausage production ingredient. The sausage formulation that came closest to the control in terms of acceptability is the one that contained 5 per cent blood. The savings in productioncost can be translated as extra earnings for the slaughterhouse operator or processor when all other factors are held constant. These findings agree with (Limeneh et al., 2022) that up to 15 per cent of slaughterhouse income could come from by-products.

Table 7: Cost Analysis of 1 kg Sausage Production at Different Fat Replacement Levels with Blood

Item	Control cost USD	5% blood USD	10% blood USD
Meat	1.8	1.8	1.8
Fat	0.5	0.25	0.125
Blood	-	0	0
Ingredients	0.3	0.3	0.3
Additives/seasonings	0.03	0.03	0.03
Packaging	0.03	0.03	0.03
Transport	0.1	0.1	0.1
Labour	0.05	0.05	0.05
Total	2.81	2.56	2.435

5.0 CONCLUSION AND RECOMMENDATIONS

Conclusions: The study found that Low-fat sausages can be processed by using as much as 10% blood to directly replace fat without significantly affecting the physicochemical and sensory properties of the sausage. Blood sausages were also less susceptible to chemical deterioration during storageas compared to other traditional sausages. Blood can be a cheaper substitute for the animal fat used in sausage formulation, reducing production costs by 13.35 per cent. What's more, production of sausages with blood presents an opportunity to increase income among processors, as blood is usually wasted.

Recommendations: Further research needs to be done on bioavailability. It is also important to find the impact of antioxidants as preservatives on the shelf life.

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