Research Article

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The incorporation of *Moringa oleifera* leaves powder in mutton patties: Influence on nutritional value, technological quality, and sensory acceptability

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Abstract: Meat is a highly nutritious food rich in protein, fat, vitamins, and minerals. Nevertheless, chemical reactions and microorganisms might affect the quality of nutritional constituent of meat products. This study investigated the influence of adding *Moringa oleifera* leaves powder (MOLP) on the nutritional, technological properties, and consumer acceptability of mutton patties. Four treatments of mutton patties with 0, 0.3, 0.6, and 0.9% of MOLP were produced. The prepared patties (raw and cooked) were evaluated for quality attributes such as proximate composition, total phenolic content (TPC), cooking properties (cooking yield and cooking loss), physical characteristics (colour and water holding capacity [WHC]), thiobarbituric acid reactive substances (TBARS), pH value, and sensory quality. The incorporation of MOLP into the mutton patties significantly increased ($p < 0.05$) protein, fat, ash contents, TPC, pH, WHC, and cooking yield. However, moisture content, TBARS, and colour decreased. Most sensory likability scores of patty samples with up to 0.3% of MOLP were comparable to those of the control sample. Evidently, the inclusion of 0.3% of MOLP produces mutton patties with high sensory desirability.

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1 Introduction

Recently, changes in consumption patterns emerging from population growth have resulted in consumers searching for healthier and affordable food with acceptable taste and physical appearance [1]. Therefore, food industries continuously seek to develop and modify formulations designed to enhance quality, safety as well as extended shelf life of food [2]. Many studies have demonstrated that there is relationship between consumption of meat and the prevalence of health conditions such as coronary heart diseases and some types of cancers [3]. Moreover, consumption of saturated fats containing food or high caloric contents such as meat and its products is associated with obesity and overweight [4].

Fat content is related to desirable sensory characteristics of meat patties such as juiciness and mouth feel, and low fat content has a negative influence on the texture and sensory properties of processed meat products [5]. The main strategies that are currently used in the reformulation of meat products involve reducing the fat content and improving the fatty acid profile [6]. Therefore, ingredients such as flours of cereal and legume, gums, modified starches, and proteins are added to meat products to reduce the fat content [7]. This results in meat products retaining high amounts of moisture and fat, thereby improving its juiciness and decreasing its hardness. Different plant extracts such as *Moringa oleifera* (MO) seed, lupine, and Bambara groundnut flours have been utilised in meat patties as non-meat fat replacement, fillers, binders, or extenders [8,9].

MO is the most commonly cultivated species of the Moringaceae family [10]. Its leaves and flowers are good

source of protein and dietary fibre with an adequate profile of amino acids and ash [11,12]. The leaves are also rich sources of minerals such as calcium, potassium, zinc, magnesium, iron, and copper [11]. MO leaves are utilised to increase the shelf life of foods since they are rich sources of antioxidants such as phenolics, flavonoids, carotenoids, and ascorbic acid [13]. The leaves and seeds of MO have important medicinal properties that include antioxidant, antibacterial, and antifungal activities and have been evaluated as natural preservative for different types of meat products [14–16].

The leaves of MO have shown their potential to be used as a functional ingredient in meat products such as ground meat and patties as dried powder or extract. Research on the utilisation of MO leaves extract as a functional food ingredient to modify the nutritive characteristics of foods such as yoghurt, cheese, bread, sauces, juices, biscuits, and soup, among others, is increasing [17]. There are few studies on the utilisation of MO leaves on the processed meat products such as patties particularly those using mutton meat. Al-Juhaimi et al. [9] studied the influence of MO seed flour on quality characteristics of beef burgers. Das et al. [18] studied the influence of MO leaves extract in the prevention of lipid oxidation in cooked goat meat patties. However, the utilisation of MO leaves as a non-synthetic preservative in mutton patties has not been sufficiently explored. Therefore, this study evaluated the influence of MO leaves powder (MOLP) on the nutritional, technological, and sensory attributes of mutton patties.

2 Materials and methods

2.1 Materials

Five kg of boneless mutton meat for each batch was obtained from a commercial supermarket (Thohoyandou, South Africa). MO leaves were obtained from the University of Venda's experimental farm (22.8785° S, 30.4818° E). All chemicals and reagents used in this experiment were of analytical grade.

2.2 Preparation of MOLP

MO leaves were soaked in a 5 L bucket with distilled water and washed to eliminate dirt and foreign particles from the leaves' surfaces. Afterwards, the leaves were spread out on a tray to drain out water and air-dried for 20 min. MO leaves were dried using an oven dryer (Model OTE 80. ProLab, South Africa) with slight modification at 30°C for 72 h. The dried leaves were milled using Retsch Miller (Ultra Centrifugal Mill ZM 200, Retsch, Germany) and the ring sieve produced a final fine powder (40 µm) due to the aperture size of 1.50 mm. The milled powder was sieved using a sieve size of 40 µm to ensure fine-textured powder. The powder was transferred into a polyethylene bag, kept in a closed bag and stored at room temperature until it was used.

2.3 Preparation of mutton patties

Approximately three batches of 5 kg of fresh boneless mutton meat were obtained from a local butchery, Thohoyandou, South Africa. The meat was cut into slices using a hand knife and ground using meat mincer (model FHG 7552, Freddy Hirsch, South Africa). To obtain similar emulsions for each burger formulation, MOLP was stirred manually with cold distilled water in a beaker at the same ratio (1 g of powder/2 mL of water) for 30 s and allowed to rest for 10 min for better hydration. The MOLP was dispersed uniformly and different levels (0, 0.3, 0.6, and 0.9%) were added to ground meat. Ground meat was divided into equal portions of 50 g each and formed into patty disks using the manual machine. A microwave was used to grill the patties for 5 min at 700 MHz until the internal temperature reached 80°C and then cooled at room temperature for 1 h before weighing. The raw and cooked patties were then stored in a polyethylene bag for further use with head space air to allow oxidation to take place unless inhibited by antioxidants. The entire production and analyses of mutton patties were replicated three times.

2.4 Physical properties of formulated mutton patties

2.4.1 Measurement of colour

Spectrophotometer Lovibond (model no: LC 100, RM 200, Minolta, China) with a D65 light source and a 10° observer was used for colour measurements (L^*, a^*, and b^* values) of mutton patties. Chroma (C^*) and hue angle ($H°$) were also recorded. Hue was calculated as $H = \tan^{-1}(a/b)$. Colour was measured at room temperature on raw and cooked patties' internal surface and three different locations were scanned during measurement.

2.4.2 Water holding capacity (WHC)

The method of Wardlaw et al. [19] was followed to determine the WHC of the raw mutton patties. Briefly, 10 g of raw mutton patties was placed in a centrifuge tube with 12 mL of NaCl (0.6 M). A glass rod was used to stir the mixture for 1 min and the test tube was then kept for 15 min at 5°C and then centrifuged at 1,000 rpm for 25 min. The mixture was measured and WHC was expressed as a 100 g of raw mutton patties.

$$\text{WHC (\%)} = (\text{Initial volume of NaCl (mL)} - \text{Volume of the supernatant}) / (\text{Weight of the sample}) \times 100.$$

2.4.3 Determination of cooking properties

A method described by Naveena et al. [20] was used to measure the cooking yield of mutton patties:

$$\text{Cooking yield (\%)} = \frac{\text{Weight of cooked patties}}{\text{Weight of raw patties}} \times 100. \quad (1)$$

The cooking loss was measured based on the method of Aleson-Carbonell et al. [21] as follows:

$$\text{Cooking loss (\%)} = \frac{\text{Weight of raw patties} - \text{weight of cooked patties}}{\text{Weight of raw patties}} \times 100. \quad (2)$$

2.5 Determination of the content of basic chemical components and polyphenols in mutton patties

The proximate composition of raw and cooked mutton patties was analysed as per AOAC [22] procedure. The moisture content of patties was determined according to the AOAC method 945.32 with oven drying at 105°C for 3 h. Ash content was determined using the muffle furnace according to the AOAC method 923.03. Crude protein was determined using the Kjeldahl method, and AOAC method 978.02 and 6.25 × N were used to multiply the nitrogen content to obtain protein percentage. The fat content was determined according to the AOAC method 920.39.

The total phenolic content (TPC) was determined through the Folin–Ciocalteu reagent assay following the method described by Slinkard and Singleton [23]. About 2 g of each sample was weighed and transferred into a beaker and 20 mL of methanolic acid (10%) was added and sonicated for 10 min in an ultrasonic bath and then centrifuged at 5,000 rpm for 10 min and then filtered. After that, 0.5 mL of sample was transferred into test tubes and mixed with 1.5 mL of Folin–Ciocalteu reagent. The mixture was allowed to rest for 5 min at room temperature. Approximately 2 mL of sodium carbonate (7%) was added after 5 min and incubated for 45 min in a dark area with occasional shaking. After incubation, the absorbance of samples was measured at 725 nm using UV-visible spectrophotometer microplate reader. Results were expressed as mg GAE/g.

2.6 pH value of formulated mutton patties

The pH value of mutton patties was determined by a pH meter (BASIC 2.0 pH meter, Crison instrument, S.A. EU). Buffers of different pH concentrations (4.00 and 8.00) at 25°C were used to calibrate pH meter before measurement. The glass rod of pH meter was directly inserted into the sample of mutton patties. Different parts of mutton patties were used to record four readings each time and these were averaged.

2.7 Determination of thiobarbituric acid reactive substances (TBARS) of mutton patties

The TBARS value was determined following the method of Rosmini et al. [24]. About 10 g of meat was mixed with 20 mL of 10% of tricloracetic acid and homogenised at 724×*g*. The samples were centrifuged at 10°C for 30 min. The mixture was filtered using filter paper and 2 mL of the filtrate was added with an equal quantity of TBA 20 mM (Sigma-Aldrich, South Africa). Afterwards, the mixture was vortexed and incubated in a water bath for 20 min at 98°C. Tap water was used to cool the samples at ambient temperature of 25°C at the end. Spectrophotometer (Shimadzu UV-1800 Spectrophotometer, Kyoto, Japan) was used to measure the absorbance of the samples at 532 nm. A standard curve of malonaldehyde (MDA) was used to calculate TBARS values and expressed as mg MDA/kg sample.

2.8 Sensory evaluation and acceptability of mutton patties

Eighty untrained regular meat patty consumers participated in the study; they included students and staff of

University of Venda (Thohoyandou, South Africa), of both gender, aged between 18 and 60. Mutton patty samples were cooked in the electric oven for 40 min at 120°C. Sensory attributes such as taste, colour, juiciness, tenderness, and overall acceptability were evaluated using a nine-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely). Panelists were given 15 g of each sample labelled with a random three-digit number and served warm. Tap water was given to the panelists to rinse their mouth after each sample testing. The acceptability index (AI) was calculated according to the formula:

$$\text{AI } (\%) = \frac{A \times 100}{B}, \tag{3}$$

where, A = mean grade obtained for the product and B = maximum grade given to the product.

Informed consent: Informed consent has been obtained from all individuals included in this study.

Ethical approval: The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance with the tenets of the Helsinki Declaration, and has been approved by the Internal Ethics Committee of University of Venda, Thohoyandou, South Africa.

2.9 Statistical analysis

The analyses were performed in triplicates. The results were presented as mean values ± standard deviation. The SPSS software (version 23.0, IBM SPSS, Armonk, NY, United States) was used to analyse the data. One-way analysis of variance (ANOVA) was employed, and mean values of results for each experiment were differentiated using the Duncan's multiple range test. Differences with p values of less than 0.05 were considered significant.

3 Results and discussion

3.1 Colour measurement of formulated patties

Results of colour measurement of raw and cooked mutton patties added with MOLP are presented in Table 1. There was a significant decrease in L^* values of both raw and cooked mutton patties with increase in MOLP level, ranging from 41.23 to 33.45. The decrease in L^* value of formulated patties might be due to lower moisture proportion with the incorporation of MOLP, since moisture is associated with the lightness values [25]. Moreover, changes in the meat matrix which involves the alterations in the free water during cooking might also have contributed to the decrease in L^* value in cooked burgers. Turhan et al. [26] noted that the high concentration of wet *okara* contributed to the lighter colour of beef patties. In addition, Naveena et al. [27] reported a decrease in L^* value of chicken patties due to the inclusion of pomegranate rind powder extract. The control sample of raw patties had the maximum lightness value of 41.23 and patties added with 0.9% of MOLP had the lowest lightness value of 33.45. Low values of lightness in mutton patties added with MOLP is likely due to chlorophyll which negatively affected haemoglobin, thereby reducing the lightness of patties [28].

The a^* value for raw patties sample significantly decreased ($p < 0.05$) ranging from 6.59 to 4.38. The

Table 1: Colour measurements of raw and cooked mutton patties added with MOLP

Sample	L^*	a^*	b^*	C^*	Hue angle
Raw mutton patties					
Control	41.23 ± 1.71^{e}	6.59 ± 0.42^{g}	9.49 ± 1.26^{a}	11.56 ± 1.16^{a}	55.06 ± 3.18^{a}
0.3% of MOLP	39.33 ± 1.12^{d}	5.06 ± 0.36^{f}	11.30 ± 30.51^{b}	12.41 ± 0.58^{c}	65.96 ± 1.06^{b}
0.6% of MOLP	37.08 ± 2.02^{bc}	4.66 ± 0.39^{e}	12.33 ± 0.53^{d}	13.18 ± 0.44^{de}	69.28 ± 2.11^{bc}
0.9% of MOLP	33.45 ± 1.99^{a}	4.38 ± 0.40^{d}	13.24 ± 0.24^{e}	13.95 ± 0.35^{e}	71.71 ± 1.22^{c}
Cooked mutton patties					
Control	40.13 ± 1.02^{de}	2.27 ± 0.80^{c}	11.73 ± 3.23^{c}	11.97 ± 3.22^{b}	78.63 ± 4.32^{d}
0.3% of MOLP	39.67 ± 0.93^{d}	0.43 ± 0.42^{a}	15.13 ± 1.76^{f}	15.14 ± 1.75^{f}	88.26 ± 1.83^{e}
0.6% of MOLP	38.73 ± 1.33^{c}	0.60 ± 0.20^{b}	15.73 ± 0.50^{g}	15.75 ± 0.50^{g}	87.80 ± 0.80^{e}
0.9% of MOLP	36.47 ± 2.14^{b}	0.23 ± 0.12^{a}	16.43 ± 0.65^{h}	16.44 ± 0.65^{h}	89.20 ± 0.38^{e}

Results are expressed as mean values ± standard deviation. Means sharing the same letters in column are not significantly different from each other ($p > 0.05$). MOLP: *Moringa oleifera* leaves powder.

control sample had a^* value of 6.59. This may be attributed to oxidation of myoglobin, metmyoglobin formation as well as antioxidant potential of MOLP [29]. The a^* value was lower in cooked patties compared to raw patties. The a^* value for cooked mutton patties ranged from 0.23 to 2.27. The control patties sample had the maximum a^* value, while patties treated with 0.9% of MOLP had the lowest value. Similar results were obtained by García et al. [30] for patties incorporated with tomato powder and they concluded that the Maillard reaction during cooking might have contributed to colour changes in patties.

There was a significant ($p < 0.05$) increase in b^* values of both raw and cooked mutton patties with increase in the concentration of MOLP ranging from 9.49 to 16.43. With increase in MOLP, cooked mutton patties showed greater yellowness compared to raw patties. This shows that MOLP affected the b^* value and the increase in b^* values may be due to the presence of carotenoids and xanthophylls present in MOLP. This finding is in line with Serdaroglu [7] who reported that the incorporation of oat flour increased the yellowness of beef patties.

The C^* values ranged from 11.56 to 16.44 and increased with increase in the concentration of MOLP. The C^* values for cooked mutton patties were higher than that of raw patties with increase in the MOLP concentration. Moreover, there was a significant difference ($p < 0.05$) in chroma values of both raw and cooked mutton patties. Therefore, the addition of MOLP increased colour intensity of mutton patties. Nkukwana et al. [31] reported similar results whereby the incorporation of MO leaf meal increased the chroma of chicken breast meat.

The H° values of mutton patties added with MOLP were significantly ($p < 0.05$) higher than the control sample in both raw and cooked mutton patties ranging from 55.06 to 89.20. This shows that there was an increase in H° values with an increase in the concentration of MOLP. Yousuf and Srivastava [32] and Zahid et al. [33] stated that low a^* and C^* values and high H° values indicate meat discolouration due to their positive association with concentration of metmyoglobin in cooked beef and minced meat. The result of this study is in line with Nkukwana et al. [31] who reported higher H° and C^* values of chicken breast meat supplemented with MO leaf meal.

3.2 Technological properties of mutton patties

The technological attributes of mutton patties are shown in Table 2. The WHC of meat is described as the compatibility of meat to hold added water or its own water during meat processing. It is seen as a significant quality measurement attribute in determining the option of utilising meat in the processing of meat products [34]. The WHC of raw mutton patties added with MOLP was significantly ($p < 0.05$) higher than the control at different concentrations. The control sample had lower WHC value and this could be attributed to minor denaturation of sarcoplasmic proteins [35,36]. The values of WHC ranged from 64.56 to 67.19%, with control of raw patties being the lowest at 64.56%. Syedziauddin [37] stated that the decrease in WHC in processed meat products could be due to the utilisation of meat from very old animals that possess lower WHC. Moreover, Muthukumar et al. [29] stated that the addition of MO leaves extract resulted in an increase in the WHC of goat meat and raw pork patties. Sharma and Yadav [38] reported similar results whereby the incorporation of pomegranate peel, bagasse powder, and their extracts increased the WHC of chicken patties. These results demonstrate that the inclusion of ingredients from fruit or vegetable in meat patties yields a tender and juicier product. This shows that the incorporation of plant based ingredients positively influences the ability of meat products to hold water.

Properties such as cooking loss and cooking yield are the most crucial quality characteristics of meat products. The results show that the cooking yield of raw mutton

Table 2: Technological properties of mutton patties added with MOLP

Sample	WHC (%)	Cooking yield (%)	Cooking loss (%)
Control	64.56 ± 0.45^a	62.16 ± 1.34^a	37.84 ± 1.56^d
0.3% of MOLP	65.71 ± 0.70^b	67.20 ± 1.62^b	32.80 ± 1.35^c
0.6% of MOLP	65.87 ± 0.40^b	70.01 ± 1.73^c	29.99 ± 1.32^b
0.9% of MOLP	67.19 ± 0.60^c	73.13 ± 2.06^d	26.87 ± 1.22^a

Values are mean values ± standard deviation of triplicate determinations. Means sharing the same letters in column are not significantly different from each other ($p > 0.05$). WHC: water holding capacity; MOLP: *Moringa oleifera* leaves powder.

patties increased as the concentration of MOLP increased and the incline rate was significant ($p < 0.05$). Results of cooking yield ranged from 62.16 to 73.13% with the increase in MOLP concentration. The increase in cooking yield values is associated with retention of fat and water [34]. Lario et al. [39] stated that fat and WHC are related to the cooking performances improvement with the incorporation of orange peel because of their soluble constituents, mostly pectin, which might comprise up to 25% of the tissue. Rocha-Garaz and Zayas [40] also indicated that quality traits, for instance, structural binding, texture, and yield in meat products, are determined by the protein matrix being able to bind fat and retain water. In this view, fibre and carbohydrates are effective in enhancing cooking yield, thereby reducing the cost of formulas and improving the texture of meat products. Cooking yield of mutton patties improved with the incorporation of MOLP due to its capacity to retain water and fat as well as its ability to keep moisture in the matrix of meat patties [21]. Similar results were obtained by Alakali et al. [41] whereby the incorporation of Bambara groundnut flour improved the cooking yield of beef patties.

There was significant difference ($p < 0.05$) between the control and formulated mutton patties with regards to cooking loss. The incorporation of MOLP level at 0.9% was effective in decreasing the cooking loss when compared to control mutton patties sample followed by 0.6% of concentration. This might be due to the inclusion of MOLP which inhibited the degradation of sarcoplasmic and myofibrillar proteins that are responsible for the increase in cooking loss of meat products [42]. Higher cooking loss in control mutton patties sample could be due to denatured meat protein during cooking as well as the destruction of cell membrane and shrinkage of meat fibres [43]. Mahmoud et al. [34] observed that cooking loss of beef patties improved when orange peels were included. Apparently, orange peels are good binders of fat and water. Therefore, low cooking loss of mutton patties might indicate that MOLP could utilise a protective role against denaturation of protein [44]. Subha et al. [45] reported a reduction in cooking loss of cooked *rohu* fillets treated with crude extracts from MO leaves. Moreover, addition of Wanggasi-Chunnyuncho (*Opuntia humifusa f. jeollaensis*) fruit powders led to a significant decrease in the cooking loss of pork sausage [46].

3.3 Nutritional composition and TPC of formulated mutton patties

Table 3 shows the influence of MOLP on the proximate composition and TPC of the raw and cooked mutton patties. The moisture content of raw patties ranged from 65.50 to 60.08% and showed a significant ($p < 0.05$) decrease with increase in MOLP. The control sample had the highest moisture content whereas mutton patties with 0.9% of MOLP had the lowest moisture content. The decrease in moisture content of raw mutton patties might be attributed to higher solid contents of MOLP. Bilek and Turhan [47] reported similar results of low moisture content of beef patties incorporated with flaxseed flour. The moisture content of cooked mutton patties decreased significantly ($p < 0.05$) as the percentage of MOLP increased, ranging from 58.63 to 54.56%. This could be attributed to the inclusion of MOLP (0.9%) which would decrease the binding in the meat matrix, while small amount (0.3% of MOLP) improves the binding [21]. Moreover, cooked mutton patties had lower moisture content compared to that of raw patties since cooking results in moisture loss via drip loss and evaporation.

Table 3: Nutritional composition and TPC of raw and cooked mutton patties added with MOLP

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	TPC (mg/100 g)
Raw mutton patties					
Control	65.50 ± 1.41^{g}	1.12 ± 0.02^{a}	22.85 ± 1.62^{c}	5.17 ± 0.46^{a}	22.14 ± 2.25^{a}
0.3% of MOLP	62.05 ± 0.74^{f}	1.18 ± 0.04^{b}	24.66 ± 0.85^{e}	6.77 ± 0.80^{c}	25.36 ± 3.41^{b}
0.6% of MOLP	60.97 ± 0.57^{c}	1.23 ± 0.02^{c}	26.11 ± 2.43^{f}	6.48 ± 0.55^{b}	26.54 ± 1.08^{bc}
0.9% of MOLP	60.08 ± 2.88^{d}	1.24 ± 0.02^{c}	28.91 ± 0.54^{f}	7.21 ± 1.59^{b}	28.70 ± 1.00^{c}
Cooked mutton patties					
Control	58.63 ± 0.64^{a}	1.27 ± 0.13^{d}	21.12 ± 0.64^{a}	12.10 ± 0.78^{d}	42.74 ± 3.12^{d}
0.3% of MOLP	56.08 ± 1.31^{b}	1.34 ± 0.08^{e}	22.03 ± 0.18^{b}	13.26 ± 0.80^{e}	45.98 ± 1.60^{e}
0.6% of MOLP	55.98 ± 2.17^{b}	1.45 ± 0.09^{f}	22.13 ± 0.24^{b}	13.38 ± 0.52^{e}	50.33 ± 4.60^{f}
0.9% of MOLP	54.56 ± 1.08^{c}	1.50 ± 0.11^{g}	23.32 ± 0.81^{d}	18.32 ± 0.90^{f}	54.59 ± 4.23^{g}

Results are expressed as mean values ± standard deviation. Means sharing the same letters in column are not significantly different from each other ($p > 0.05$). MOLP: *Moringa oleifera* leaves powder; TPC: total phenolic content.

The ash content of both raw and cooked mutton patties ranged from 1.12 to 1.50%. Ash content of mutton patties significantly increased ($p < 0.05$) with increase in the concentration of MOLP. The increase in ash content might be due to MOLP since it is a rich source of minerals such as calcium, potassium, zinc, magnesium, iron, and copper [48]. Similar results were reported by Valenzuela-Melendres et al. [1] whereby the addition of flaxseed flour and tomato paste increased the ash content of beef patties. However, Valenzuela-Melendres et al. [49] did not observe any significant difference ($p < 0.05$) between the ash content of control and formulated beef patties when they added up to 10% of flaxseed flour.

The protein content of both raw and cooked mutton patties ranged from 21.12 to 28.91% and fat content varied from 5.17 to 18.32%. Protein and fat content of mutton patties significantly increased ($p < 0.05$) with increase in the concentration of MOLP. The increase in protein, fat, and ash contents of patties because of the inclusion of MOLP is likely due to moisture loss, increase in the amount of total solids as well as the influence of MOLP concentration [50]. High protein content of patties might also be due to the phenolic compounds in MOLP because plant extracts have a protective effect against protein denaturation in processed meat products [51]. Moreover, the increase may be associated with the richness of MO in these constituents. Similar trends were observed by Mashau et al. [52] and Elhadi et al. [50] whereby incorporation of MOLP improved the protein and fat content in ground beef and chicken patties.

The TPC values of both raw and cooked mutton patties significantly increased ($p < 0.05$) with the increase in MOLP levels, ranging from 22.14 to 54.59 mg/100 g. The increase in TPC value of mutton patties added with MOLP is due to MOLP being a good source of antioxidants. Sreelatha and Padma [53] reported the TPC of 45.81 mg/g in MOLP. The same authors reported that MOLP is also a rich source of flavonoids. Therefore, phenolic compounds, including flavonoids, probably contributed to high values of TPC in raw and cooked mutton patties. The slight increase in TPC of cooked patties is likely due to the inactivation of oxidative enzymes by heat during cooking. Oxidative enzymes such as phenolase and peroxidases result in greater losses of phenolic compounds during thermal processing of food [54]. The results of this study correspond with findings of Mashau et al. [28,52] who stated that the inclusion of MOLP and MO leaf extract triggered significant increase ($p < 0.05$) in TPC in raw ground beef and mutton patties. The higher values of TPC in mutton patties added with MOLP suggest that the incorporation of MOLP nutritionally enriched mutton patties.

3.4 TBARS and pH of mutton patties

Table 4 shows the influence of MOLP concentration on TBARS and pH of raw and cooked mutton patties. The TBARS values of both raw and cooked mutton patties significantly decreased ($p < 0.05$) with an increase in the MOLP level, ranging from 0.82 to 0.59 mg/kg. The high amounts of phenolic compounds such as naphthoquinones, phenolic acids, and flavonoids contained in MOLP might have contributed to low TBARS values in mutton patties added with MOLP [18]. Free radical chains of oxidation are believed to be broken down by natural antioxidants through the donation of hydrogen from the polyphenolic groups which result in the formation of a stable product [55]. These results agree with those by Lalas and Tsaknis [56] who stated that Moringa seed flour is a rich source of antioxidants due to its high activity that inhibit rancidity development. In addition, Hygreeva et al. [57] demonstrated that the inclusion of lemon albedo is very effective in inhibiting lipid oxidation in fresh and processed meat products. Lipid in meat and meat products is easily oxidised, and the resulting hydroperoxides produce secondary lipid oxidation products such as aldehydes and ketones which contribute to off-flavour, thereby reducing quality [58,59]. Therefore, utilisation of plants such as MO in meat industry might provide safe products with extended shelf life and higher nutritional value since they are rich sources of bioactive compounds with pro-health implications [60].

The pH of raw and cooked mutton patties at different concentrations of MOLP was significantly ($p < 0.05$)

Table 4: TBARS and pH of raw and cooked mutton patties added with MOLP

Sample	TBARS (mg/kg)	pH
Raw mutton patties		
Control	0.73 ± 0.11^{d}	5.87 ± 0.04^{a}
0.3% of MOLP	0.64 ± 0.05^{b}	5.97 ± 0.01^{b}
0.6% of MOLP	0.61 ± 0.05^{ab}	5.97 ± 0.02^{b}
0.9% of MOLP	0.59 ± 0.04^{a}	5.99 ± 0.04^{b}
Cooked mutton patties		
Control	0.82 ± 0.07^{f}	6.10 ± 0.01^{c}
0.3% of MOLP	0.79 ± 0.01^{e}	6.10 ± 0.03^{c}
0.6% of MOLP	0.68 ± 0.04^{c}	6.11 ± 0.01^{c}
0.9% of MOLP	0.68 ± 0.08^{c}	6.20 ± 0.01^{d}

Results are expressed as mean values ± standard deviation. Means sharing the same letters in column are not significantly different from each other ($p > 0.05$). TBARS: thiobarbituric acid reactive substances; MOLP: *Moringa oleifera* leaves powder.

Table 5: Sensory quality and acceptability of mutton patties added with MOLP

Sample	Taste	Colour	Juiciness	Tenderness	Overall acceptability
Control	8.20 ± 0.60^{c}	8.00 ± 0.02^{c}	7.24 ± 0.22^{a}	7.14 ± 0.08^{a}	8.06 ± 0.25^{c}
AI (%)	92.02	91.00	80.50	79.16	89.90
0.3% of MOLP	8.00 ± 0.58^{c}	7.90 ± 0.33^{c}	7.86 ± 0.32^{b}	7.78 ± 0.13^{b}	7.85 ± 0.56^{c}
AI (%)	88.70	88.90	87.10	85.50	86.82
0.6% of MOLP	7.10 ± 0.20^{ab}	7.20 ± 0.22^{b}	7.98 ± 0.50^{bc}	7.88 ± 0.42^{bc}	6.90 ± 0.20^{b}
AI (%)	80.00	82.52	89.68	87.77	76.25
0.9% of MOLP	6.90 ± 0.40^{a}	6.78 ± 0.60^{a}	8.20 ± 0.42^{c}	8.00 ± 0.37^{c}	5.96 ± 0.89^{a}
AI (%)	76.40	75.22	92.03	91.00	70.02

Results are expressed as mean values ± standard deviation. Means sharing the same letters in column are not significantly different from each other ($p > 0.05$). AI: acceptability index; MOLP: *Moringa oleifera* leaves powder.

higher than the control sample. The recorded pH values of raw and cooked mutton patties ranged from 5.87 to 6.20. A higher pH of meat contributes to lower L^* (lightness) as shown in Table 1 and this indicates that meat with high pH is darker than meat with normal pH of 5.5 [61]. Putrefaction by microorganisms might have contributed to the variation in pH values among raw and cooked patties [9]. In addition, the increase in pH values of mutton patties might be due to glycogen content in mutton patties [62]. On the other hand, low pH values of raw patties are desirable in patties manufacturing since microbial growth are inhibited, thereby, improving the shelf life of patties [63]. The result of this study corresponds with Sayas-Barberá et al. [64] who reported an increase in pH values of cooked beef burgers added with date pits extracts.

3.5 Sensory quality and acceptability of mutton patties

Table 5 shows the influence of MOLP on the sensory quality and acceptabiliy of cooked mutton patties. The inclusion of plant extracts negatively affects the quality of meat products and the general challenge is to keep them at a concentration similar to the full-meat product [9]. The incorporation of MOLP decreased the sensory attributes of cooked patties such as colour, taste, and overall acceptability except for tenderness but the decrease was insignificant. There was no significant difference ($p > 0.05$) between 0.3% of MOLP and the control sample in all sensory characteristics due to the addition of only a small amount of MOLP. The decrease in sensory attributes such as colour and taste might be due to moisture loss and dehydration of formulated mutton patties [65]. Low values of colour score might be related to the green colour of MOLP arising from its chlorophyll content since consumers are more familiar with the brown colour of cooked patties [52]. Moreover, the bitter taste of MOLP likely contributed to the low score of taste in the formulated patties. Sensory attributes such as colour and tenderness which influence consumers to accept meat and meat products rely on the capacity of meat to hold water [66]. Low overall acceptability scores of patties added with MOLP might be reflective of the low scores of colour and taste [67]. The negative effect of incorporating plant extracts on sensory quality and acceptability of meat products such as patties has been reported by other researchers [9,68]. Valenzuela-Melendres et al. [49] also observed that the incorporation of flaxseed flour at 0–10% had a negative influence on the overall acceptability of beef patties. The oxidation of polyunsaturated fatty acids available in flaxseed was attributed to such results. The incorporation of functional ingredients such as MOLP and flaxseed flour in concentrations that improve the nutritional quality is related to low acceptability of food, especially because of the flavour of the final product [69].

4 Conclusion

Utilisation of MOLP at 0.3, 0.6, and 0.9% each had positive antioxidant effects in raw and cooked mutton patties. Low TBARS values in formulated patties might be attributed to the inhibition of lipid oxidation by MOLP which contains polyphenols that have antioxidant effects. Moreover, the inclusion of MOLP enhanced the quality characteristics of mutton patties by enriching the protein and ash, reducing moisture content and cooking loss, and increasing cooking yield and WHC. The results of this study show that MOLP can be utilised as a natural preservative in mutton patties since it contains polyphenols, and up to 0.3% of MOLP can be used without altering sensory properties. Despite this,

more research is needed to determine the shelf life of cooked mutton patties added with MOLP.

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