Physicochemical properties and shelf life stability of meat products: effect of mosambi peel powder

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Objective: The aim was to utilize the mosambi peel, a by-product of juice industry in buffalo meat products to enhance the functional and physicochemical properties and more importantly determine its effect on the fiber content of meat.

Methods: Sausages and patties were prepared from buffalo meat incorporated with mosambi peel powder (MPP) and were evaluated for various physicochemical, cooking and sensory qualities along with storage stability. The lean meat was replaced with MPP at a concentration of 0%, 2%, 4%, 6%, and 8%.

Results: Addition of MPP enhanced the fiber content of both sausages and patties and increased the fat and moisture content. Decrease in red color and increase in yellow color was observed as indicated by decrease in L and a* value and increase in b* value. High cooking yield and emulsion stability with less dimensional change indicated that incorporation of MPP enhanced the cooking qualities of both sausages and patties. It was also observed that peel powder incorporated sausage and patties had a hard texture compared to controls. Up to the 6% incorporation the product had good overall acceptability however sensory score decreased with an increase in incorporation level. Storage stability in terms of thiobarbutaric acid, yeast and mould and total plate count showed that incorporation of MPP increased the shelf life of sausages and patties.

Conclusion: It was concluded that MPP has a potential to be used as functional ingredient in meat products as MPP enhanced the functional properties and storage stability of meat products.

Keywords: Red Meat; Meat Products; Mosambi Peel; Dietary Fiber; Shelf Life

INTRODUCTION

Red meat includes meat of beef, lamb, veal and pork, is considered one of the nutritious and delicious foods, containing high amount of essential amino acids. The presence of high amount of myoglobin is peculiar to red meat and responsible for the color of meat. In the last couple of decades the consumption of fresh red meat and processed red meat has increased world-wide [1]. Various researchers have linked the red meat and processed meat consumption with the development of chronic disease [2-4]. Several hypotheses have been proposed for the carcinogenesis of red meat to cause colon cancer. It was proposed that colon cancer causes due to the production of heterocyclic aromatic amines during meat cooking and generation of potentially mitogenic diacylglycerol compounds from fat in the intestines and the presence of nitrate or nitrites used in the processed meat. However this hypothesis failed to explain non-cancerous effect of white meat. Later, it was observed that the red meat contains heme, which is having low absorption in the intestines and hence reaches the colon and causes colon cancer [5]. In October 2015 International Agency for Research on Cancer has considered red meat to be one of the causing agents of colon cancer.
and recommended that processed meat should be avoided and less than 500 g of fresh meat should be consumed per week [6].

The carcinogenic effect of meat can be reduced by several methods. Allam et al [7] reported that addition of calcium carbonate and chlorophyll to the red meat binds to the heme component and thus eliminate the carcinogenic effect of meat. The incorporation of dietary fiber in red meat products can reduce transit time of heme compounds after digestion in the colon to cause any carcinogenic reaction with colon cells. Also the soluble portion of dietary fiber increases the viscosity of digested food in the colon and may restrict the movement of heme molecules to cause carcinogenic reactions. In addition to this dietary fiber have various health benefits like reducing the body’s low-density lipo proteins, abrupt increase in body glucose level and providing the healthy gut environment by producing short chain fatty acids. Dietary fiber from plant sources have added advantage of having bioactive compounds like polyphenols which can enhance shelf life of meat by reducing the fat oxidation [8].

Mosambi (Citrus Limetta) a valuable fruit consumed in the form of juice. Peel is the by-product of juice extraction process and is a rich source dietary fiber. The peel of mosambi is bitter in taste which hinders its use in human foods. However, in our previous study, we have successfully removed its bitterness with the help of sodium chloride and sodium bicarbonate to make it edible [9]. Mosambi peel has significantly increased the dietary fiber content of papaya jam and cookies in our previous studies [9, 10]. As meat is deficient in dietary fiber and due to its chronic health hazards, this work tried to convert red meat into a functional food. Different types of fibers have been tried in the various meat products but to our best knowledge, the mosambi peel has not been tried in any kind of meat product yet. So, the aim of this work was to find the possibility of incorporation of mosambi peel powder (MMP) in buffalo meat sausages and patties and its effect on their quality parameters.

MATERIALS AND METHODS

Mosambi peel powder
Mosambi peel was procured from the local juice vendors and then washed and dried. The peels were salted to remove the bitterness and dried by using method adopted by Younis et al [9]. Mosambi peel was ground up to the size of 18 British Standard Sieve and was then packed hermetically and storage at –18°C for further analysis.

Buffalo meat
The meat and fat was obtained from the healthy animal with the age group between 1 to 2 years old and was slaughtered by the halal method. Both lean meat and fat were stored for overnight in a deep freezer at –18°C for easy grinding. Both lean meat and fat were passed separately through a meat mincer (Sirman TC 12 E; Sirman, Curtarolo, Italy) plate pore size of 6 mm.

Sausages and patties preparation
Sausages and patties were prepared separately using same recipe. MPP was incorporated at a rate of 0% (control), 2%, 4%, 6%, and 8% in both sausages and patties by replacing the lean meat. The 100 g base recipe was prepared for sausages and patties by mixing sodium chloride (1.6 g), sodium nitrite (0.015 g), spice mix (1.9 g), condiments paste (3 g), ice (8 g), and minced fat (10 g) to ground lean meat (75.49 g). Meat batter was prepared for the sausages and patties in bowl chopper and the temperature was kept low by using ice cubes. After bowl chopping the sausage and patties preparation differ from each other. The sausages are stuffed into the synthetic casing, linked and steam cooked at 100°C for 30 minutes. Whereas patties were molded in patty molder and cooked in an oven until the internal temperature reaches 75°C to 80°C.

Proximate analysis
The moisture, protein and fat content of sausages and patties were analyzed using the standard AOAC [11] method numbers of 925.1, 981.10, and 920.85 and respectively. Dietary fiber both soluble and insoluble content was determined by AOAC [12] method.

pH analysis
The pH of sausages and patties was measure by using the digital pH meter by mixing the 15 g sample in 30 mL of distill water at 25°C to 27°C [13].

Emulsion stability
Emulsion stability was determined using the method adopted by Kondaiah et al [14]. Uncooked batter (20 g) of sausages and patties were heated in airtight bags at boiling temperature in water bath for 20 min. Emulsion stability was determined as:

\[
\text{Emulsion stability} \% = \frac{\text{Weight of heated sample}}{\text{weight of sample}} \times 100
\]

Cooking yield
The cooking yield of sausage and patties were determined using the method adopted by Gadekar et al [15]. The weight of sausage and patties were observed before and after cooking and results obtained were used to calculate cooking yield as:

\[
\text{Cooking yield} \% = \frac{\text{Weight of cooked sample}}{\text{Weight of raw sample}} \times 100
\]
Dimensional changes
The dimensional analysis of sausage and patties were determined using the method adopted by Serdaroğlu and Değirmencioğlu [16]. Dimensional analysis of sausage were determined by measuring change in reduction in diameter %, while as dimensional analysis of patties were determined by measuring the change in reduction in diameter %, thickness %, and shrinkage %.

\[
\text{Reduction in diameter (\%)} = \frac{\text{Uncooked sausage /patty diameter} - \text{cooked sausage /patty diameter}}{\text{uncooked sausage /patty diameter}} \times 100
\]

\[
\text{Reduction in thickness (\%)} = \frac{\text{Uncooked patty thickness} - \text{cooked patty thickness}}{\text{uncooked patty thickness}} \times 100
\]

\[
\text{Shrinkage (\%)} = \frac{(\text{Raw thickness} - \text{cooked thickness}) + (\text{Raw diameter} - \text{cooked diameter})}{\text{Raw thickness} + \text{raw diameter}} \times 100
\]

Color analysis
Hunter color instrument MiniScan XE Plus was used for the color analysis of sausages and patties. The instrument was calibrated with black and white standard plates before color measurement. Internal color of sausages and patties was measured by peeling the outer layer of products by a knife.

Texture analysis
Textural properties of sausages and patties were measured at room temperature by using the texture analyzer (Stable Micro Systems, Godalming, England). Texture profile analysis of meat products was done by using the method of Bourne [17]. Samples were cut into cubes of 50 mm length and 15 mm height. During the test setting for measurement was selected as pre-test speed (1 mm/s), test speed (2 mm/s), posttest speed (2 mm/s), time (5 s), strain (50%), and trigger force (5 g).

Sensory analysis
Sensory analysis of sausages and patties was carried out by using a nine-point hedonic scale with a range of 1 to 9. Where 9 indicates extremely like and 1 indicates extremely dislike. Trained panelists were selected including the faculty members and research scholars of the department. Brunch time was selected for the sensory analysis in order to eliminate the effect of hunger or fullness. Sausages and patties were warmed in an oven and provided to the panelists in a white disposable plate along with drinking water. The products whose overall rating was above 6 were considered acceptable by the sensory panelists.

Shelf life analysis
Shelf life study was carries out only to the products having highest acceptability. The products having 6% MPP incorporation were having highest overall acceptability. Hence only products with 6% MPP were selected for shelf life study. The shelf life study of sausages and patties was carried out under refrigerated conditions for 21 days. The samples were analysed for thiobarbituric acid (TBA), yeast and mold count and total plate count on 5th, 10th, 15th, and 20th day of storage time. However, sensory analysis was performed on 6th, 11th, 16th, and 21th day of storage after confirming the total plate count of samples is under range.

Evaluation of thiobarbituric acid number
The TBA number was estimated as per the method described by Strange et al [18]. The TBA reagent was prepared by mixing 90% acetic acid with 0.28 g of TBA to make the final volume of 100 mL. Sample of 2 g was mixed with the 5% of trichloroacetic acid (10 mL) and then centrifuged at 3,500 rpm for 10 minutes. The supernatant was filtered through the Whatman No.1 filter paper (Merck KGaA, Darmstadt, Germany). Filtered samples of 5 mL were taken and mixed with the 5 mL of TBA reagent which was vortexed and incubated at 100°C for 30 minutes in a water bath along with the control sample prepared with 5 mL of each trichloroacetic acid and TBA. After cooling the samples the absorbance was measured at 530 nm (Digital spectrophotometer Model 301; Electronic India, Parwanoo, Himachal Pradesh, India). The TBA number was calculated with the help of standard concentration curve of malonaldehyde with 1, 1, 3, 3-tetraetoxipropane. The TBA number was expressed in mg malonaldehyde per kg sample.

Evaluation of microbiological characteristics
Total plate count and yeast mold count was estimated by using the spread plate method as described by Harrigan and McCance [19]. Nutrient agar medium was used for total plate while as potato dextrose agar was for used yeast and mold count. A sample of 10 g each from sausage and patties was cut and comminuted under sterile conditions. This was mixed with the 90 mL of 0.1% sterile peptone solution from which different serial dilution was done up to 10⁻⁶ and 0.1 mL from each dilution was spread on the plates with the help of spreader. The inoculated plates were incubated at 37°C for 24 to 48 hours. The number of microorganisms present in the sample was calculated with the help of given below equation.

\[
\text{Total plate and yeast mold count} = \frac{\text{Number of Colonies}}{\text{Amount plated} \times \text{Dilution}}
\]

Evaluation of sensory characteristics
Sensory analysis of sausages and patties during the storage
RESULTS AND DISCUSSION

Proximate analysis of sausages and patties

Table 1 shows the effect of MPP incorporation on the proximate composition of sausages and patties. It was observed that moisture content increased significantly (p≤0.05) in both sausage and patties with addition of MPP. The increase in moisture content can be attributed to higher water binding capacity of MPP [9]. The higher water binding capacity of MPP prevents the water loss of both sausage and patties during cooking. Hence higher percentage of MPP, lower is water loss during and higher is the moisture content. Sausages had higher moisture content than patties at each level of MPP incorporation. The higher moisture content in sausages may be attributed to the presence of casing and stream cooking. Protein content of both sausages and patties decreased significantly (p≤0.05) at each level of MPP incorporation. The decrease in protein content after MPP incorporation may be attributed to low protein content in MPP. The lower moisture content in patties than sausages resulted in proportional increase in protein content in patties compared to sausages. The fat content of both sausages and patties increased significantly (p≤0.05) with the incorporation of MPP. This may be due to higher oil binding capacity of MPP that holds the fats during cooking of sausages and patties [9]. Higher fat was observed in sausages than patties and this could be attributed to the presence of casing and difference in the method of cooking.

Dietary fiber content of sausages and patties

Meat and meat products are deficient in dietary fiber due to which its high consumption is associated with chronic diseases. Incorporation of MPP in meat sausages and patties has significantly (p≤0.05) increased their dietary fiber content as shown in Table 1. The increase in fiber content in both patties and sausage after incorporation of MPP is due to higher percentage of fiber in MPP [10]. Increase in fiber content of patties and sausages increase their health benefits. In the study of Bastide et al [21] it was reported that red meat was responsible for colon cancer. They reported that the presence of heme

Table 1. Effect of mosambi peel powder incorporation on proximate composition of sausages and patties

<table>
<thead>
<tr>
<th>MPP %</th>
<th>pH</th>
<th>Moisture</th>
<th>Protein</th>
<th>Fat</th>
<th>IDF</th>
<th>SDF</th>
<th>TDF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5%</td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
<td>8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sausages</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>6.25 ± 0.03a</td>
<td>62.60 ± 0.51b</td>
<td>16.09 ± 0.29b</td>
<td>4.83 ± 0.29b</td>
<td>0.33 ± 0.02bc</td>
<td>0.13 ± 0.03d</td>
<td>0.46 ± 0.05e</td>
</tr>
<tr>
<td>2</td>
<td>6.16 ± 0.02a</td>
<td>63.17 ± 0.29bc</td>
<td>15.74 ± 0.36bc</td>
<td>6.50 ± 0.51bc</td>
<td>1.69 ± 0.35bc</td>
<td>0.59 ± 0.10d</td>
<td>2.27 ± 0.26e</td>
</tr>
<tr>
<td>4</td>
<td>6.13 ± 0.02bc</td>
<td>63.39 ± 0.14bcd</td>
<td>15.33 ± 0.37bcd</td>
<td>8.03 ± 0.17bcd</td>
<td>2.79 ± 0.40bcd</td>
<td>0.83 ± 0.10d</td>
<td>3.61 ± 0.49f</td>
</tr>
<tr>
<td>6</td>
<td>6.09 ± 0.02cd</td>
<td>64.13 ± 0.33cde</td>
<td>14.90 ± 0.36cde</td>
<td>10.93 ± 0.13cde</td>
<td>3.72 ± 0.23cde</td>
<td>1.66 ± 0.10cde</td>
<td>5.39 ± 0.32g</td>
</tr>
<tr>
<td>8</td>
<td>6.04 ± 0.04de</td>
<td>64.46 ± 0.58fde</td>
<td>14.48 ± 0.37fde</td>
<td>11.09 ± 0.11fde</td>
<td>4.83 ± 0.21fde</td>
<td>2.50 ± 0.10fde</td>
<td>7.33 ± 0.25h</td>
</tr>
<tr>
<td>Patties</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>6.54 ± 0.02a</td>
<td>61.00 ± 0.50bc</td>
<td>16.35 ± 0.31bc</td>
<td>2.95 ± 0.42bc</td>
<td>0.33 ± 0.01bc</td>
<td>0.08 ± 0.03bc</td>
<td>0.41 ± 0.04cd</td>
</tr>
<tr>
<td>2</td>
<td>6.42 ± 0.02b</td>
<td>62.07 ± 0.55bcd</td>
<td>15.80 ± 0.16bcd</td>
<td>4.85 ± 0.19bcd</td>
<td>1.84 ± 0.62bcd</td>
<td>0.42 ± 0.26bcd</td>
<td>2.26 ± 0.37cd</td>
</tr>
<tr>
<td>4</td>
<td>6.31 ± 0.02bc</td>
<td>62.48 ± 0.45bcd</td>
<td>15.46 ± 0.12bcd</td>
<td>8.80 ± 0.73bcd</td>
<td>2.76 ± 0.54bcd</td>
<td>0.43 ± 0.26bcd</td>
<td>3.19 ± 0.80cde</td>
</tr>
<tr>
<td>6</td>
<td>6.25 ± 0.05cd</td>
<td>63.16 ± 0.29cde</td>
<td>14.99 ± 0.10cde</td>
<td>10.22 ± 0.29cde</td>
<td>3.66 ± 0.20cde</td>
<td>1.16 ± 0.10cde</td>
<td>4.82 ± 0.27cde</td>
</tr>
<tr>
<td>8</td>
<td>6.18 ± 0.01de</td>
<td>63.55 ± 0.33fde</td>
<td>14.79 ± 0.27fde</td>
<td>10.78 ± 0.23fde</td>
<td>4.34 ± 0.10fde</td>
<td>1.90 ± 0.10fde</td>
<td>6.24 ± 0.17fde</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation.
MPP, mosambi peel powder; IDF, insoluble dietary fibre; SDF, soluble dietary fibre; TDF, total dietary fibre.
** Means with different superscripts in a column did differ significantly (p<0.05).
compound in meat reacts with colon cells and causes adenocarcinoma. The presence of fiber content in meat reduces their transient time in intestines and thus reduces the time for reaction between carcinogenic compounds and colon cells. This suggests that presence of fiber content in meat could negate the carcinogenic effect of meat. Similar results were reported for bologna sausages incorporated with citrus fiber [8].

**Color of sausages and patties**

Table 2 shows the effect of MPP incorporation on the colour of both sausages and patties. It was observed that L* value of both patties and sausages increased significantly (p≤0.05) after MPP incorporation. The increase in L* could be attributed to the lighter colour of MPP powder. L* value of patties was found lower than that of sausages at each corresponding level of MPP incorporation. The lower L* of patties could be attributed to the surface browning caused by dryheat cooking [22]. The color of red meat is mainly due to the myoglobin and the reflectance of proteins. During cooking this red color changes from pink-red to brown due to the formation of met myoglobin. Further, the red color of meat products can be affected due to the addition of non-meat ingredients. With the increase of MPP incorporation in both sausages and patties, a* values decreased significantly (p≤0.05). Similarly, with the incorporation of MPP, the b* values of sausages and patties decreased significantly (p≤0.05). The decrease in b* value was due to the effect of MPP incorporation which is having the light yellow color. Higher b* values of sausages were also observed than the patties at each corresponding level of MPP incorporation. This was due to the effect of dry cooking of patties which causes more browning in the products [22].

**Cooking yield of sausages and patties**

Table 3 shows the effect of MPP incorporation on cooking yield of sausages and patties. It was observed that cooking yield significantly (p≤0.05) increased with the incorporation of MPP, indicating the desirable effect of MPP on cooking quality of sausage and patties. Improvement in cooking yield indicates the low cooking loss. Similar results were reported for burger added with albedo fiber [23]. The improvement in cooking yield by MPP incorporation can be attributed to the higher fiber content of MPP having good water binding and oil binding capacity [24]. Sausages showed higher cooking yield compared to the patties at each level of MPP incorporation. This may be attributed to the casing in sausage which prevents the cooking loss and hence higher cooking yield.

**Emulsion stability of sausages and patties**

Table 3 shows the results of emulsion stability of sausages and patties incorporated with MPP. It was found that the emulsion stability increased significantly (p≤0.05) with the increase of MPP incorporation for both sausages and patties. The increase in emulsion stability may be due to the good water and oil holding capacity of MPP. Abirami et al [25] reported that emulsion activity and emulsion stability of citrus peel was high. High emulsion activity and stability of citrus peel may be the reason for increased emulsion stability of sausages and patties incorporated with MPP.

**Dimensional changes of sausages and patties**

Dimensional changes during cooking of meat and meat products are common phenomena. The changes in dimensions of meat and meat products are due to the heating of meat proteins and loss in moisture which leads to the shrinkage. Dimensional changes in sausages were determined by observ-

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**Table 2. Effect of mosambi peel powder incorporation on color of sausages and patties**

<table>
<thead>
<tr>
<th>MPP (%)</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>36.78 ± 0.50d</td>
<td>15.76 ± 0.31a</td>
<td>14.18 ± 0.28b</td>
<td>34.09 ± 0.21d</td>
<td>17.53 ± 0.48a</td>
<td>12.6 ± 0.35c</td>
</tr>
<tr>
<td>2</td>
<td>37.57 ± 0.30cd</td>
<td>14.98 ± 0.08b</td>
<td>15.26 ± 0.28c</td>
<td>35.82 ± 0.24c</td>
<td>16.51 ± 0.44a</td>
<td>13.5 ± 0.34c</td>
</tr>
<tr>
<td>4</td>
<td>38.75 ± 0.29bc</td>
<td>14.29 ± 0.24bc</td>
<td>15.95 ± 0.07bc</td>
<td>36.68 ± 0.33bc</td>
<td>15.04 ± 0.32b</td>
<td>14.74 ± 0.51b</td>
</tr>
<tr>
<td>6</td>
<td>39.56 ± 0.31b</td>
<td>13.30 ± 0.36c</td>
<td>16.72 ± 0.15d</td>
<td>38.90 ± 0.40b</td>
<td>13.20 ± 0.48c</td>
<td>16.96 ± 0.23a</td>
</tr>
<tr>
<td>8</td>
<td>43.14 ± 1.01a</td>
<td>11.72 ± 0.72d</td>
<td>18.79 ± 0.93a</td>
<td>41.46 ± 0.55a</td>
<td>10.67 ± 0.31d</td>
<td>17.66 ± 0.49a</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation.
MPP, mosambi peel powder.
**Means with different superscripts in a column did differ significantly (p < 0.05).**

**Table 3. Effect of mosambi peel powder addition on cooking quality of sausages and patties**

<table>
<thead>
<tr>
<th>MPP %</th>
<th>Sausages</th>
<th>Patties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cooking yield</td>
<td>Emulsion stability</td>
</tr>
<tr>
<td>0</td>
<td>64.03 ± 0.96d</td>
<td>63.84 ± 0.60e</td>
</tr>
<tr>
<td>2</td>
<td>70.80 ± 0.72e</td>
<td>70.91 ± 0.37e</td>
</tr>
<tr>
<td>4</td>
<td>72.23 ± 0.68e</td>
<td>77.24 ± 0.92e</td>
</tr>
<tr>
<td>6</td>
<td>81.29 ± 0.62c</td>
<td>83.90 ± 1.09b</td>
</tr>
<tr>
<td>8</td>
<td>86.32 ± 0.59b</td>
<td>88.87 ± 0.82b</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation.
MPP, mosambi peel powder.
**Means with different superscripts in a column did differ significantly (p < 0.05).**
ing change in diameter reduction while as in case of patties dimensional changes were determined by observing change in diameter reduction, thickness and shrinkage. Figure 1A shows the diameter reduction in sausages. It was observed that the percent decrease in diameter was less in MPP incorporated sausage than in control sausages. The drop in diameter reduction was proportional with increase in MPP level incorporation. This may be attributed to the water holding capacity of MPP which resists the water loss during cooking and hence less diameter reduction. This suggests that the shrinkage of meat product during cooking is an undesirable process but is a natural phenomenon which can be prevented by incorporation of MPP. Similarly in case of patties the increase in thickness and less reduction in diameter was observed (Figure 1B). From the results of thickness and diameter the overall shrinkage was observed. The overall shrinkage of patties was reduced significantly (p≤0.05) with incorporation of MPP. The overall results indicate that incorporation of MPP in meat sausages and patties showed desirable effect on dimension.

Texture properties of sausages and patties

Table 4 shows the effect of MPP incorporation on the textural properties of sausages and patties. It was found that the hardness, firmness, and toughness of sausages and patties increased significantly (p≤0.05) with the incorporation of MPP, while as, the springiness got decreased. It was further observed that hardness, firmness, and toughness of patties were found higher than that of sausages at respective levels.
of MPP incorporation. The ranges of share force and two bite test for sausages and patties incorporated with MPP were found as hardness 68.23 to 87.44 and 70.50 to 90.64 N, firmness 17.67 to 27.00 and 20.86 to 31.40 N, toughness 215.79 to 290.52 and 224.01 to 300.63 N sec and springiness 0.83 to 0.72 and 0.84 to 0.74 respectively. Similar results were found by Fernández-Ginés et al [8] for bologna sausages. They reported that hardness and less springiness of sausages increased with the addition of citrus fiber. The texture of meat products depends on the various factors like fat content, water content, particle size of lean meat and non-meat ingredients, etc. According to Han and Bertram [26] the effect of fiber on the texture of meat products depends upon the type of fiber. The soluble fiber enhances the strength of meat products while insoluble fiber shows the vice versa. The presence of soluble dietary fiber in MPP forms a three-dimensional gel which disrupts the protein-water or protein-protein interactions and forms a new network which increases the cohesiveness thus increases the tenderness and strength of the product. However, the insoluble portion of dietary fiber does not form gels but absorbs the water from the adjacent molecules due to which the hard and brittle texture is produced.

Table 4. Effect of mosambi peel powder addition on textural properties of sausages and patties

<table>
<thead>
<tr>
<th>MPP %</th>
<th>Sausages</th>
<th>Patties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hardness</td>
<td>Springiness</td>
</tr>
<tr>
<td>0</td>
<td>68.23 ± 0.88&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.83 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>71.88 ± 0.37&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.82 ± 0.01&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>76.75 ± 0.84&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.79 ± 0.01&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>6</td>
<td>83.04 ± 2.19&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.77 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>8</td>
<td>87.44 ± 0.97&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.72 ± 0.01&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values are mean ± standard deviation.
MPP: mosambi peel powder.
**Means with different superscripts in a column did differ significantly (p<0.05).

Sensory analyses of sausages and patties

The results of the sensory analysis of sausages and patties incorporated with different levels of MPP are presented in Figure 2. Different sensory parameters were analyzed through nine-point hedonic scale like color, flavor, texture, taste, bitterness, juiciness and mouth coating. The average of all sensory parameters was denoted with the overall acceptability. From the results, it was concluded that with an increase in MPP concentration in both sausages and patties the sensory score decreased significantly (p<0.05) which has been illustrated in the respective figures. Sausages and patties were accepted up to the 6% incorporation of MPP beyond that the products got low scores. The decrease in juiciness, texture, and bitterness was prominent in both sausages and patties at the 8%. The decrease in juiciness might be due to the transfer of moisture from the meat proteins to the MPP. This may attributed to the higher water affinity of MPP. This has the inverse relationship with the moisture content, as indicated in from the results of proximate composition; the incorporation of MPP increased the moisture content which in turn decreased the juiciness in sensory analysis. The lower textural scores can be correlated with the instrumental texture analysis where the hardness has increased with the MPP incorporation which is not desirable. And finally, there might be some residual bitterness present in MPP whose threshold values became visible at higher incorporation levels of MPP.

Shelf life

Thiobarbituric acid number: The TBA number is an important parameter used to determine the oxidative state and rancidity of the products. During the storage exposure of oxygen to emulsion sausages and patties may lead to develop warm over flavour (WOF). Development of WOF during storage was evident during sensory analysis which provides an idea of fat oxidation in stored samples. From the Figure 3 the TBA number of the fresh control samples (patties and sausages) was found in the range of 0.88 to 1.00 mg/kg, which has increased during refrigerated storage period of 20 days up to 3.63 mg/kg for sausage and 2.35 mg/kg for patties. This may be attributed to the microbial growth and fat oxidation during the storage. Also the TBA values for sausages were found higher than the patties. This may be due to low fat content of patties as the fat loss is higher in the dry cooking. With the incorporation of MPP the TBA number remained below 1 mg/kg during 20 days of storage. This might be due the presence of bioactive compounds bearing the antioxidant and antimicrobial properties in the fruit by-products [27-29]. According to Campo et al [30] the recommended TBA number value should be less than the minimum threshold value of 1 to 2 mg malonaldehyde/kg meat during the storage period. However, Tarladgis et al [31] reported that the minimum threshold of TBA number was detected at the concentration of 0.50 to 1.0 mg/kg by the panellists. These differences may be due to the use of trained and untrained sensory panellists. Emulsion sausages and patties incorpo-
rated with MMP had TBA values lower than the threshold values as described above. However, the control samples had high TBA number greater than the threshold values of 1 to 2 mg/kg, indicating the desirable effect of fruit by-products on the fat oxidation.

Yeast and mould count: Yeast and mould count (log cfu/g) of sausages and patties samples are presented in Figure 4A. It was found that the yeast and mould count of the control was found significantly (p≤0.05) less than the samples incorporated with MMP during fresh conditions. During refrigerated storage yeast and mould count increased significantly (p≤0.05) in MMP incorporated samples. This may be due to the acidic nature of MMP which permitted the selective growth of yeast and mould. It was also observed that the yeast and mould count was found less in sausages than patties. This may be due to the low moisture content of patties than sausages samples. Cumaria (2002) [32] reported that when log cfu/g of yeast and mould count increases up to 4.0 spoilage of food starts. From this point of view the spoilage of sausages and patties was not noticeable due to yeast and mould.

Total plate count: Total plate count is one of the important microbiological parameters used to determine the shelf life of the product. The neutral pH and the rich nutrients present in meat provide the best atmosphere for the growth of bac-
Figure 3. Effect of mosambi peel powder on TBA values of sausages and patties. CP, control patties; CS, control sausages; S, mosambi peel powder incorporated sausages; P, mosambi peel powder incorporated sausages; TBA, thiobarbituric acid.

Figure 4. (A) Yeast and mold count of patties and sausages (B) Total plate of sausages and patties. CS, control sausages; CP, control patties; MP, mosambi peel powder incorporated patties; MS, mosambi peel powder incorporated sausages; CFU, colony forming units.
Increased microbial population causes degradation of protein and fat into simpler compounds like fatty acid, amines, ammonia etc. [33] due to which the product develops off flavour on spoilage. From the Figure 4B it was observed that the total plate count of sausages and patties in fresh condition was not significantly (p≤0.05) different. However, the total plate count of control sausages and patties was found significantly (p≤0.05) higher than the MMP incorporated sausages and patties during the storage period of 20 days. This may be due to the antimicrobial compounds like polyphenols present in the MMP. It was also observed that the total plate count of sausages was found higher than that of respective patties during the period of storage. This may be due to the high moisture content of sausages than patties which favours the growth of bacteria. Borch et al [34] described that the spoilage conditions are noticed when total plate count reached to total $10^7$/g. From this point of view, the control sausages and patties were found unsuitable for consumption after 10th day of storage. While as the MMP incorporated sausages was found unsuitable for consumption on 20th day. The patties incorporated with MPP were found acceptable during the whole storage life period.

Sensory of sausage and patties during storage
The sensory evaluation of controlled and MPP incorporated sausages and patties is been shown in Figure 5. Sensory characteristics were measured in terms of sensory attributes namely colour, flavor, texture, taste, juiciness and overall acceptability. Sensory analysis was performed next day after the microbial analysis so as to ascertain the safety of the panelists. All the samples were compared with their respective control samples on the particular day of analysis. A significant (p≤0.05) difference was observed between the control sausages and patties with their MPP incorporated sausages and patties on the first day of sensory analysis. During the storage periods the observed sensory score of the entire samples decreased because of microbial growth, increase in TBA number and loss of juiciness. The sensory analysis of control sausages and patties was not carried out on eleventh and sixteenth day of storage respectively because they were not

![Figure 5](https://example.com/sensory_analysis.png)

**Figure 5.** Sensory analysis of stored sausages and patties. CS, control sausages; CP, control patties; MS, mosambi peel powder incorporated sausages; MP, mosambi peel powder incorporated patties.
safe for consumption as per the microbial analysis. Similarly, the MMP incorporated sausages and patties were not analyzed for sensory analysis on the twenty first day of storage. From the results it was concluded that the fruit wastes has increased the shelf life of sausages and patties as compared to the control samples. This may be due to the polyphenolic and antioxidant activities present in the fruit wastes.

**CONCLUSION**

The results of this work have shown that MMP has potential to be used as a functional ingredient in meat industry, besides use of mosambi peel is economical. Further, it can help to eliminate the negative taboo of meat on health. Also, themosambi peel is rich in dietary fiber which significantly enhances the dietary fiber content of meat products. In addition to fiber enrichment, the cooking qualities have been improved after peel powder incorporation. The textural properties such as hardness, toughness, and firmness of sausages and patties have increased with the incorporation of MPP. From the sensory scores, it was found that up to 6% incorporation of MPP the products were acceptable beyond this concentration the products were unacceptable because of textural and quality defects. The presence of secondary metabolites in MMP prevents the microbial growth as well as reduces the fat oxidation in sausages and patties with the result improvement in shelf life. Controlled use of MMP in meat products can enhance the fiber content of meat which is deficient in fiber and will improve the shelf life stability of meat products.

**CONFLICT OF INTEREST**

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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