



Improving shelf-life of raw pork and pork meatballs by starfruit (*Averrhoa carambola*) powder supplementation

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ABSTRACT

The study was conducted to evaluate the effect of starfruit (*Averrhoa carambola*) powder on the storage stability of both raw minced pork and cooked pork meatballs. Starfruit powder was incorporated to raw minced pork as well as pork meatball mixture at the rate of 1.0%, 1.5% and 2.0% based on w/w basis. Samples with starfruit powder had lowered Thiobarbituric acid reactive substances (TBARS) value and improved microbiological quality of the product was observed, when stored at refrigeration temperature ($4\pm1^{\circ}\text{C}$) for a period of 21 days. The product had better physico-chemical properties, desirable textural properties and enhanced sensorial characteristics. All these attributes lead to enhancement of the overall acceptability of the treated product. It indicated that starfruit powder can successfully be utilized as additives to raw pork and pork meatball mixtures to obtain products having improved shelf-life and can act as functional foods.

Key words: Minced pork, Pork meatball, Shelf-life, Starfruit powder

Meat and meat products serve as a concentrated source of nutrients comprising of proteins of high biological value as well as amino acids, fatty acids, vitamins and elements, making them an essential component of human diet. Due to its composition, meat and its products are prone to microbial spoilage and lipid oxidation. These deteriorative changes are generally controlled by adding synthetically derived antimicrobials and antioxidants. The effect of prolonged consumption of such chemicals on human health has created a quandary among consumers and legislation and are rushing towards naturally derived alternatives which would not root any significant health risk.

It is well established that agricultural co-products and by-products are rich in natural antioxidants and antimicrobials (Balasundram *et al.* 2006, Tiwari *et al.* 2009). Studies related to effect of starfruit powder on meat is very limited. Thomas *et al.* (2016) demonstrated the antioxidant and anti-microbial properties of starfruit juice on pork nuggets and Vivar-Vera *et al.* (2018) enriched Vienna sausages with starfruit dry fibre concentrate.

In this study emphasis was given towards evaluating the antioxidant and antimicrobial effect of starfruit powder (SFP) on raw minced pork as well as on cooked pork meatballs stored under refrigerated ($4\pm1^{\circ}\text{C}$) temperature. The physico-chemical characteristics, textural properties and sensory parameters of the cooked meatball was also studied.

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MATERIALS AND METHODS

Starfruits were purchased from local market. These were thoroughly washed, cleaned, dried and transversely cut into thin slices. These were then dried in a hot air oven at $47\pm2^{\circ}\text{C}$ for approximately 24 h. Dehydrated starfruit slices were then ground to a fine powder using a laboratory mill and sieved through a fine mesh. These samples were then aerobically packed in UV sterilized Low Density Polyethylene (LDPE) containers and stored in blast freezer at $-18\pm1^{\circ}\text{C}$.

Freshly cut pork samples were collected from slaughter houses run by the Government of West Bengal. Visible fat and tendon were removed. The meat was minced in two steps, firstly by using 10 mm plate and then by 5 mm plate. To the minced meat SFP was added on w/w basis at the rate of 0% for control (CR), 1.0% (R1), 1.5% (R2) and 2.0% (R3).

Meatballs were prepared as described by Kumar (2001) with slight modifications. The ingredients required were procured from the local market. For this purpose lean meat was used and was minced. For the dry spice mix all the ingredients were first dried in a hot air oven at 50°C for 4 h and were ground into a fine powder. The condiment mixture was prepared by blending peeled and sliced onion, ginger and garlic in the ratio 3:1:1 in a grinder till it became a smooth paste.

Minced pork along with other ingredients were used to prepare four batches of meatballs namely control batch with 0% SFP (CM), treatment 1 with 1.0% SFP (M1), treatment 2 with 1.5% SFP (M2) and treatment 3 with 2.0% SFP (M3)

Table 1. Meatball formulations

Ingredient (%)	Treatment			
	CM	M1	M2	M3
Minced lean pork	70%	69%	68.5%	68.0%
Rice bran oil	7.0%	7.0%	7.0%	7.0%
Ice flakes	8.70%	8.70%	8.70%	8.70%
Salt	1.6%	1.6%	1.6%	1.6%
Tripolyphosphate	0.3%	0.3%	0.3%	0.3%
Sugar	0.3%	0.3%	0.3%	0.3%
Dry spice powder	1.8%	1.8%	1.8%	1.8%
Condiment mixture	4.0%	4.0%	4.0%	4.0%
Refined wheat flour	3.0%	3.0%	3.0%	3.0%
Egg albumin	1.285%	1.285%	1.285%	1.285%
Sodium nitrite	0.015%	0.015%	0.015%	0.015%
Starfruit powder	0%	1.0%	1.5%	2.0%

as represented in Table 1. Meatball mixture (25 g), was then moulded into balls manually using a metal shaper having both diameter and thickness of 3.5 cm (Serdaroglu *et al.* 2004). These balls were placed in metal containers and then steam cooked at 6.8 kg/cm² pressure and 121°C temperature for 20 min (Kumar *et al.* 2013).

Antioxidant effect of SFP and thiobarbituric acid reactive substances (TBRAS) values on samples of raw pork and cooked pork meatballs were determined as per procedure given by Tarladgis *et al.* (1960) on 0, 3, 7, 14 and 21 days of storage at refrigerated (4±1°C) temperature. Anti-microbial activity of SFP on raw pork and cooked pork meatballs was determined by procedures established by APHA (2001). Total plate count (TPC), total psychrotrophic count (TPSC), total coliform count (TCC) and yeast and mould count (YMC) was conducted on 0,3,7,14 and 21 days of storage at refrigerated (4±1°C) temperature. For all the microbiological analysis readymade media from Hi-Media Laboratories Ltd., Mumbai, were used. For each plate four replicates were prepared and the counts were expressed as colony forming units (cfu) per gram.

For studies related to cooked meatballs, the percentage moisture, crude protein, fat and ash were determined by methods described by AOAC (2001). Texture profile

analysis was conducted on day zero using the procedure described by Bourne (1978) using a TA-HDi Texture Analyzer (Stable Micro Systems, UK). For determination of pH, 10 grams of the meatball sample was homogenized with 50 ml distilled water (Troutt *et al.* 1992) using a mortar and pestle. The pH of the suspension was recorded using a digital pH meter. Standard equations were applied to determine the % moisture retention (El-Magoli *et al.* 1996), % fat retention, % cooking yield (Murphy *et al.* 1975) and % shrinkage (Adams 1994) of the cooked meatball. The emulsion stability of the meatball mixture was determined by procedure established by Kondaiah *et al.* (1985).

A sensory panel of 7 judges was set up to evaluate the product for different quality attributes. For sensory evaluation the meat balls were deep fried in rice bran oil at a temperature of 150–160°C and turned upside down every 3 min till the desired brown colour was observed and an internal temperature of 65°C is attained. An 8 point hedonic scale was adopted, where 8 denoted extremely desirable and 1 unacceptable. Sensory evaluation for the afresh product was carried out at day zero.

Six sets of experiments were conducted and each experiment was replicated 4 times (n=24). All data obtained during this investigation were analysed statistically by using SPSS-24® software package. For storage studies, data were analysed using two-way ANOVA with interaction taking treatment and storage time as main effects. For physico-chemical parameters and texture profile analysis one-way ANOVA was used. To compare means, Duncan's multiple range test (Duncan 1955) was adopted. For analysis of data related to different criteria of sensory evaluation, Kruskal-Wallis H test (Kruskal *et al.* 1952) was adopted. The values were presented as mean along with standard error (Mean±SE).

RESULTS AND DISCUSSION

The effect of SFP on lipid oxidation and microbial count for both raw minced meat as well as cooked meatball stored at refrigerated (4±1°C) temperature are indicated in Table 2 and Table 3, respectively. Both TBA and microbial plate count values were recorded on 0, 3, 7, 14 and 21 days of

Table 2. Thiobarbituric acid reactive substances (TBARS) of raw minced pork and cooked pork meat ball (mg mda/kg)

Treatment	Storage days				
	Day 0	Day 3	Day 7	Day 14	Day 21
CR	0.607±0.022 ^{eA}	1.00±0.019 ^{dA}	1.544±0.026 ^{cA}	2.146±0.02 ^{bA}	2.649±0.023 ^{aA}
R1	0.579± 0.034 ^{cC}	0.95±0.021 ^{dB}	1.375± 0.034 ^{cB}	1.775± 0.024 ^{bB}	2.245± 0.046 ^{aB}
R2	0.589± 0.03 ^{eB}	0.909±0.018 ^{dC}	1.325±0.022 ^{cC}	1.726± 0.032 ^{bC}	2.072± 0.026 ^{aC}
R3	0.577±0.025 ^{eC}	0.857±0.021 ^{dD}	1.278±0.016 ^{cD}	1.621±0.038 ^{bD}	1.98± 0.03 ^{aD}
<i>Cooked pork meatballs</i>					
CM	0.321±0.015 ^{eA}	0.377±0.014 ^{dA}	0.439±0.013 ^{cA}	0.562±0.017 ^{bA}	0.706±0.013 ^{aA}
M1	0.315± 0.013 ^{eB}	0.352± 0.016 ^{dB}	0.38± 0.016 ^{cB}	0.525± 0.014 ^{bB}	0.661±0.016 ^{aB}
M2	0.307±0.014 ^{eC}	0.326± 0.015 ^{dC}	0.36±0.013 ^{cC}	0.482± 0.014 ^{bC}	0.604±0.017 ^{aC}
M3	0.298± 0.015 ^{eD}	0.315± 0.014 ^{dD}	0.355± 0.017 ^{cC}	0.408± 0.014 ^{bD}	0.521±0.016 ^{aD}

n=24. Mean±SE with different small letter superscripts in the same row differ significantly (P<0.05); Mean±SE with different capital letter superscripts in the same column differ significantly (P<0.05).

Table 3. Effect of addition of starfruit powder on the microbiological parameters of raw minced pork and cooked pork meatballs stored at refrigerated ($4\pm1^{\circ}\text{C}$) temperature ($\log_{10}$ cfu/g)

Treatment	Total plate count (TPC) for raw minced pork				
	Storage days				
	Day 0	Day 3	Day 7	Day 14	Day 21
CR	2.751 $\pm$ 0.028 ^{eA}	4.946 $\pm$ 0.027 ^{dA}	7.147 $\pm$ 0.026 ^{cA}	10.652 $\pm$ 0.030 ^{bA}	17.048 $\pm$ 0.028 ^{aA}
R1	2.748 $\pm$ 0.024 ^{eA}	4.545 $\pm$ 0.029 ^{dB}	6.449 $\pm$ 0.028 ^{cB}	9.545 $\pm$ 0.026 ^{bB}	16.448 $\pm$ 0.029 ^{aB}
R2	2.75 $\pm$ 0.029 ^{eA}	3.85 $\pm$ 0.027 ^{dC}	5.952 $\pm$ 0.025 ^{cC}	8.845 $\pm$ 0.028 ^{bC}	13.855 $\pm$ 0.025 ^{aC}
R3	2.747 $\pm$ 0.026 ^{eA}	3.352 $\pm$ 0.024 ^{dD}	5.451 $\pm$ 0.025 ^{cD}	8.242 $\pm$ 0.025 ^{bD}	12.447 $\pm$ 0.029 ^{aD}
<i>Total plate count (TPC) for cooked pork meatballs</i>					
CM	4.243 $\pm$ 0.027 ^{eB}	4.547 $\pm$ 0.026 ^{dA}	4.95 $\pm$ 0.029 ^{cA}	5.644 $\pm$ 0.03 ^{bA}	6.841 $\pm$ 0.03 ^{aA}
M1	4.347 $\pm$ 0.025 ^{eA}	3.65 $\pm$ 0.029 ^{dB}	4.25 $\pm$ 0.026 ^{cB}	5.247 $\pm$ 0.03 ^{bB}	5.948 $\pm$ 0.025 ^{aB}
M2	4.245 $\pm$ 0.028 ^{eB}	3.546 $\pm$ 0.025 ^{dC}	4.142 $\pm$ 0.028 ^{cC}	4.844 $\pm$ 0.028 ^{bC}	5.342 $\pm$ 0.028 ^{aC}
M3	4.145 $\pm$ 0.026 ^{eC}	3.448 $\pm$ 0.026 ^{dD}	3.948 $\pm$ 0.029 ^{cD}	4.348 $\pm$ 0.028 ^{bD}	4.944 $\pm$ 0.029 ^{aD}
<i>Total psychrotropic count (TPSC) for raw minced pork</i>					
CR	4.647 $\pm$ 0.025 ^{eA}	6.244 $\pm$ 0.031 ^{dA}	7.344 $\pm$ 0.026 ^{cA}	8.648 $\pm$ 0.026 ^{bA}	10.248 $\pm$ 0.026 ^{aA}
R1	4.246 $\pm$ 0.025 ^{eB}	5.839 $\pm$ 0.029 ^{dB}	6.655 $\pm$ 0.027 ^{cB}	8.15 $\pm$ 0.026 ^{bB}	9.652 $\pm$ 0.026 ^{aB}
R2	3.851 $\pm$ 0.025 ^{eC}	5.15 $\pm$ 0.028 ^{dC}	6.147 $\pm$ 0.029 ^{cC}	7.646 $\pm$ 0.025 ^{bC}	9.047 $\pm$ 0.026 ^{aC}
R3	3.348 $\pm$ 0.027 ^{eD}	4.852 $\pm$ 0.028 ^{dD}	5.643 $\pm$ 0.027 ^{cD}	7.148 $\pm$ 0.026 ^{bD}	8.647 $\pm$ 0.028 ^{aD}
<i>Total psychrotropic count (TPSC) for cooked pork meatballs</i>					
CM	1.444 $\pm$ 0.026 ^{eA}	1.845 $\pm$ 0.024 ^{dA}	2.152 $\pm$ 0.028 ^{cA}	2.655 $\pm$ 0.027 ^{bA}	3.152 $\pm$ 0.025 ^{aA}
M1	ND	ND	ND	2.346 $\pm$ 0.026 ^{bB}	2.945 $\pm$ 0.024 ^{aB}
M2	ND	ND	ND	2.249 $\pm$ 0.027 ^{bC}	2.846 $\pm$ 0.025 ^{aC}
M3	ND	ND	ND	2.152 $\pm$ 0.026 ^{bD}	2.751 $\pm$ 0.028 ^{aD}
<i>Total coliform count (TCC) for raw minced pork</i>					
CR	ND	1.251 $\pm$ 0.026 ^{dA}	1.55 $\pm$ 0.027 ^{cA}	1.946 $\pm$ 0.026 ^{bA}	2.35 $\pm$ 0.025 ^{aA}
R1	ND	ND	1.275 $\pm$ 0.011 ^{cB}	1.575 $\pm$ 0.011 ^{bB}	1.875 $\pm$ 0.011 ^{aB}
R2	ND	ND	1.26 $\pm$ 0.012 ^{cB}	1.559 $\pm$ 0.012 ^{bB}	1.86 $\pm$ 0.013 ^{aB}
R3	ND	ND	1.225 $\pm$ 0.011 ^{cC}	1.525 $\pm$ 0.01 ^{bC}	1.825 $\pm$ 0.011 ^{aC}
<i>Total coliform count (TCC) for cooked pork meatballs</i>					
CM	ND	ND	ND	1.547 $\pm$ 0.025 ^{bA}	1.85 $\pm$ 0.028 ^{aA}
M1	ND	ND	ND	ND	1.372 $\pm$ 0.015 ^{aB}
M2	ND	ND	ND	ND	1.347 $\pm$ 0.017 ^{aC}
M3	ND	ND	ND	ND	1.321 $\pm$ 0.017 ^{aD}
<i>Yeast and mould count (YMC) for raw minced pork</i>					
CR	ND	1.149 $\pm$ 0.025 ^{dA}	1.65 $\pm$ 0.029 ^{cA}	1.945 $\pm$ 0.025 ^{bA}	2.152 $\pm$ 0.024 ^{aA}
R1	ND	ND	1.274 $\pm$ 0.012 ^{cB}	1.674 $\pm$ 0.012 ^{bB}	1.872 $\pm$ 0.012 ^{aB}
R2	ND	ND	1.261 $\pm$ 0.013 ^{cC}	1.653 $\pm$ 0.018 ^{bB}	1.853 $\pm$ 0.018 ^{aB}
R3	ND	ND	1.225 $\pm$ 0.011 ^{cD}	1.625 $\pm$ 0.011 ^{bC}	1.827 $\pm$ 0.012 ^{aC}
<i>Yeast and mould count (YMC) for cooked pork meatballs</i>					
CM	ND	ND	1.151 $\pm$ 0.025 ^{cA}	1.653 $\pm$ 0.028 ^{bA}	1.851 $\pm$ 0.026 ^{aA}
M1	ND	ND	ND	1.274 $\pm$ 0.013 ^{bB}	1.375 $\pm$ 0.012 ^{aB}
M2	ND	ND	ND	1.256 $\pm$ 0.014 ^{bC}	1.356 $\pm$ 0.017 ^{aC}
M3	ND	ND	ND	1.233 $\pm$ 0.022 ^{bD}	1.334 $\pm$ 0.022 ^{aD}

n=24. Mean $\pm$ SE with different small letter superscripts in the same row differ significantly ($P<0.05$). Mean $\pm$ SE with different capital letter superscripts in the same column differ significantly ($P<0.05$).

storage. The results obtained were statistically significant ($P<0.05$) with each passing day.

It was noted that the TBA value for both raw meat as well as cooked meatball decreased significantly ($P<0.05$) with increase in percentage SFP incorporation. On day zero, no significant difference ($P>0.05$) was observed for raw pork samples treated with SFP (R1) 1.0% and (R3) 2.0%. Addition of SFP to raw minced pork at the rate of 1.0%, 1.5% and 2.0% decreased the level of MDA produced by 15.25%, 21.78% and 25.25%, respectively. Similar trends have been observed by Biswas *et al.* (2012) who studied

the effect of curry leaf and mint leaf extract on ground pork and the effect of tea catechins on beef, pork, poultry and seafoods (Tang *et al.* 2001). In case of cooked meatballs, SFP incorporation at the rate of 1% SFP, 1.5% SFP and 2.0% resulted in decrease in the levels of MDA produced by 6.37%, 14.45% and 26.20%, respectively. On day 7 of refrigerated storage no significant difference ($P>0.05$) was observed in TBARS values for 1.5% (M2) and 2.0% (M3) SFP treated cooked pork meatballs. Similar trends were observed by Thomas *et al.* (2016) who added starfruit juice as antioxidant agents to pork nuggets; Banerjee *et al.* (2015)

who added cauliflower powder as antioxidant to pork meatballs and El-Nashi *et al.* (2015) who added pomegranate peels as antioxidant to beef sausages but the extent of reduction varied because of the variation in phyto-ingredients used as well as their form of application. Meat products start exhibiting rancid flavour when MDA concentration rises above 0.6 mg/kg (Georgantelis *et al.* 2007) and after reaching a threshold limit value for rancidity of 2 mg/kg they are considered to be spoilt (Verma and Sahoo 2000). Phenolic compounds have been proven as potent antioxidant agents which increase the shelf-life of food by reducing free radical formation and lipid-peroxidation. SFP contain good amount of phenols and ascorbic acid (Gupta *et al.* 2010) moreover it is established that starfruit juice is rich in epicatechins, gallic acid, caramboflavone and pro-anthocyanides which togetherly contribute towards its antioxidant activity (Lim and Lee 2013).

Based on microbial count spoilage defects in meat become evident when the number of bacteria at the surface reaches $7 \log_{10}$ cfu/g (Jay 1992). Various phyto-ingredients have varying antimicrobial effect on raw meat and cooked meat products. It was noted that TPC, TPSC, TCC and YMC values for raw minced pork and cooked meatballs on day zero of storage did not differ significantly ($P>0.05$) but with each passing day when compared to control, addition of SFP showed significant ($P<0.05$) reduction in these values, thus extending its storage stability. Similar to the findings of Govaris *et al.* (2010) on minced sheep meat, Devatkal *et al.* (2012) on ground goat meat, Thomas *et al.* (2016) on pork nuggets and El-Nashi *et al.* (2015) on beef sausages. This effect may be due to the combined effect of low pH of

SFP and presence of anti-microbial components like flavones and glycosides (Payal *et al.* 2012). These factors increased shelf-life of both raw meat and cooked meat product by causing cell injury which ultimately leads to a prolonged lag phase and a retarded log phase. Values for different physico-chemical parameters of the cooked meatball are presented in Table 4.

It was observed that the percentage moisture, protein, fat, moisture retention and cooking yield reduced significantly ($P<0.05$) with increase in SFP concentration, but the effect on addition SFP 1.5% (M2) and SFP 2.0% (M3) on moisture and protein percentage of the cooked product did not differ significantly ($P>0.05$). This may be due to the composition of the meatball mixture where the proportion of meat gradually reduced with rise in SFP concentration, moreover acidic nature of the SFP lowered pH of meat mixture which resulted in higher fat loss and poor moisture retention in the final product and poorer cooking yield. These observations were similar to that made by Huda *et al.* (2014), Thomas *et al.* (2016), Vivar-Vera *et al.* (2018) and El-Nashi *et al.* (2015) incorporated apple pomace, starfruit juice, starfruit dry fibre concentrate and pomegranate peel to meat products, respectively. On the contrary, ash and fat retention percentage of the final product increased significantly ($P<0.05$) with increase in SFP concentration which may be a result of increase in fibre content of the meatball mixture. Addition of SFP did not bring any significant ($P<0.05$) difference in the emulsion stability of the meatball mixture.

Values displayed in Table 5 revealed the impact of SFP on textural parameters of cooked meatball. All the values observed were found to be statistically significant ($P<0.05$).

Table 4. Effect of addition of Starfruit powder on the physico-chemical parameters of cooked pork meatballs

Treatment	Moisture %	Protein %	Fat %	Ash %	pH	% Moisture retention	% Fat retention	% Cooking yield	Shrinkage %	Emulsion stability
CM	64.66± 0.330 ^a	16.4± 0.095 ^a	12.746± 0.123 ^a	2.485± 0.036 ^d	6.696± 0.041 ^a	61.509± 0.354 ^a	63.511± 0.176 ^d	94.884± 0.374 ^a	3.609± 0.188 ^d	92.271± 0.548 ^a
M1	62.628± 0.553 ^b	16.26± 0.091 ^b	11.438± 0.156 ^b	2.753± 0.056 ^c	6.373± 0.044 ^b	59.038± 0.475 ^b	75.788± 0.181 ^c	94.268± 0.267 ^b	5.232± 0.13 ^a	91.662± 0.273 ^a
M2	62.069± 0.661 ^c	16.197± 0.098 ^c	11.273± 0.185 ^c	2.857± 0.095 ^b	6.205± 0.221 ^c	58.099± 0.827 ^c	77.592± 0.155 ^b	93.615± 0.577 ^c	4.407± 0.153 ^b	91.914± 0.108 ^a
M3	61.842± 0.586 ^c	16.132± 0.103 ^c	11.054± 0.160 ^d	2.987± 0.061 ^a	6.064± 0.036 ^d	57.581± 0.482 ^d	80.679± 0.201 ^a	93.226± 0.208 ^d	3.838± 0.20 ^c	92.676± 0.182 ^a

n=24. Mean±SE with different small letter superscripts in the same column differed significantly ($P<0.05$).

Table 5. Effect of addition of Starfruit powder on the texture profile analysis parameters of cooked pork meatballs

Treatment	Hardiness (N/cm ²)	Springiness (cm)	Cohesiveness	Gumminess (N/cm ²)	Chewiness (N/cm)
CM	54.264±0.001 ^a	0.63±0.003 ^c	0.293±0.001 ^a	13.684±0.002 ^a	10.817±0.002 ^a
M1	44.484±0.002 ^c	0.648±0.002 ^b	0.252±0.002 ^b	12.853±0.003 ^b	10.719±0.002 ^a
M2	45.294±0.002 ^b	0.657±0.001 ^a	0.246±0.002 ^c	12.784±0.004 ^b	10.088±0.002 ^b
M3	40.766±0.002 ^d	0.649±0.002 ^b	0.226±0.001 ^d	9.784±0.002 ^c	7.385±0.01 ^c

n=24. Mean±SE with different small letter superscripts in the same column differ significantly ($P<0.05$).

Table 6. Effect of addition of starfruit powder on the sensory evaluation parameters of cooked pork meatballs on day zero

Treatment	Colour	Outer texture	Odour	Flavour	Tenderness	Juciness	Overall acceptability
CM	6±0.571 ^b	6.5±0.737 ^b	6.375±0.663 ^a	6.083±0.775 ^b	6.146±0.541 ^c	5.5±0.511 ^b	5.5±0.766 ^b
M1	5.667±0.458 ^d	6.688±0.749 ^a	6.333±0.761 ^a	6.188±0.942 ^a	6.333±0.584 ^a	5.625±0.448 ^a	5.792±0.706 ^a
M2	5.792±0.464 ^c	6.375±0.663 ^c	6.104±0.466 ^b	5.938±0.756 ^c	6.146±0.499 ^c	5.417±0.434 ^c	5.833±0.761 ^a
M3	6.104±0.642 ^a	6.188±0.845 ^d	6.375±0.63 ^a	6.167±0.83 ^a	6.25±0.59 ^b	5.604±0.551 ^a	5.771±0.737 ^a

n=24. Mean±SE with different small letter superscripts in the same column differ significantly (P<0.05).

It was observed that the control samples of meatballs had the highest hardness, cohesiveness, gumminess and chewiness values and SFP (1.5%) treated meatballs (M2) had the highest springiness. Cohesiveness, gumminess and chewiness reduced significantly (P<0.05) with increase in SFP concentration in the meatball mixture whereas no such trend was observed for hardness and springiness. No Significant (P>0.05) difference was observed for gumminess in 1.0% (M1) and 1.5% SFP (M2) treated meatballs, in 1.0% (M1) and in 2.0% (M3) for springiness and Control (CM) and 1.0% SFP (M1) treated meatballs for chewiness. The basis for such an outcome is that addition of SFP resulted in decrease in pH of the meatball mixture. Lower pH resulted in higher protein denaturation thus reducing the strength of the protein gel matrix resulting in poorer hardness, cohesiveness, gumminess and chewiness of the end product. Similarly, Thomas *et al.* (2016) and Vivar-Vera *et al.* (2018) stated, compared to control, the addition of starfruit juice to pork nuggets resulted in reduction of hardness, cohesiveness, gumminess, chewiness and springiness whereas addition of starfruit dietary fibre concentrate to vienna sausages resulted in no significant differences in values of gumminess and springiness but hardness increased and cohesiveness decreased with increase in starfruit dietary fibre concentration. The results for sensory evaluation of meatballs are represented in Table 6.

It was noted that treatment with 2.0% SFP (M3) resulted in the most impressive colour and odour whereas treatment with 1.0% SFP (M1) resulted in most appealing outer texture, flavour, tenderness and juiciness but the overall acceptability was highest for meatballs having 1.5% SFP (M2). Compared to control, no significant (P>0.05) effect was observed for odour in SFP 1.0% (M1) and 2.0% treatment (M3) and for tenderness in SFP 1.5% (M2) treatment. The effect of treatment with 1.0% (M1) and 2.0% SFP (M3) on flavour and juiciness did not differ significantly (P>0.05). There was improvement in overall acceptability of the product when treated with SFP but within treatments no significant (P>0.05) difference was noted. Similar results were observed by Thomas *et al.* (2016) who incorporated starfruit juice to pork nuggets.

For both raw pork and cooked pork meatballs addition of SFP proved to be effective as natural antioxidant and also improve the microbiological characteristic during storage at refrigeration temperature. Results also revealed desired textural properties and improved acceptability for

pork meatballs. Star fruit powder can be used as natural preservative for both raw pork and pork meatballs.

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