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Tenderizing Ability of *Bryophyllum pinnatum* Leaf Extract in Comparison to Papain and Bromelain on Goat Meat

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Abstract: This study aims to analyze the tenderizing ability of *Bryophyllum pinnatum* leaf extract against papain and bromelain. Papain and bromelain 0.2, 0.4, 0.6 and 0.8 % w/v (g of tenderizer /mL distilled water) and *B. pinnatum* leaf extract (g of leaves /mL distilled water) were prepared separately. The marinated goat meat chunks (50±2 g each) with salting (2% w/w) was autoclaved for 15 min at 15 psi. The rigidity index, final weight and pH were measured and the sensory analysis was evaluated. Goat meat chunks with distilled water used as a control. Based on the results of the experiments the optimum concentration of the tenderizers papain, bromelain and *B. pinnatum* leaf extract were identified as 0.2%, 0.2% and 0.6% respectively. The identified concentrations were freshly prepared again and the goat meat chunks (50±2 g each) were subjected to marinate on each tenderizers and the control with distilled water. Marinated, salted (2% w/w) chunks were autoclaved for 15 minutes at 15 psi. Rigidity index, final weight and pH were measured and the sensory attributes of tenderized goat meat was evaluated. Recorded data was analyzed using software, MINITAB 17.0. In the sensory scores, overall acceptability of the papain is 7.05 (like moderately), bromelain is 6.80 (like slightly) and *B. pinnatum* is 6.10 (like slightly) whereas the control scored 4.45 (dislike slightly). Papain and bromelain treated goat meat sample scored higher sensory values for juiciness and tenderness than the *B. pinnatum* treated goat meat. All the treatments including control show no significant difference ($P<0.05$) between the values on the sensory attribute of flavor whereas *B. pinnatum* treated goat meat scored higher sensory score for the attribute of colour with the score of 7.40 (Like moderately) than papain (3.40, dislike moderately) and bromelain (3.20, dislike moderately). Thermal yield of the goat meat treated with papain (49.5%) and bromelain (48.3%) is lower than the *B. pinnatum* treated goat meat (53.0%). Rigidity index of papain (3.9 cm^2/g) and bromelain (3.6 cm^2/g) treated goat meat is higher than the *B. pinnatum* treated goat meat (2.6 cm^2/g). In conclusion, the *B. pinnatum* leaf extract (0.6% w/v) is recommended as a cost-effective tenderizer for goat meat instead of high cost commercial meat tenderizers such as papain and bromelain.

Keywords: *Bryophyllum pinnatum* leaf extract, Goat meat, Tenderizer

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Introduction

In Sri Lanka, the annual per capita consumption of goat meat, which is a protein rich diet, was 0.09 kg in the year of 2015 and 0.12 kg in the year of 2019. The annual domestic production of goat meat was recorded as 1350 MT in 2015 and 1810 MT in 2019 (Livestock Statistical Bulletin, 2019)which emphasizes the potential demand of goat meat in Sri Lanka. The quality of meat is collectively achieved by various fresh and processed meat properties including nutritional, technological and sensory characteristics (Daniela *et al.,* 2011). Considering the sensory characteristics, tenderness is one of the crucial attributes which determine the sensory satisfaction of the consumers. Several tenderization mechanisms have been introduced to tenderize the meat for instant blade tenderization, calcium ion injection and application of proteolytic enzymes. Even though several methods have been proposed to improve the tenderness of goat meat, the application of natural tenderizers is an efficient and promising technique (Gereld *et al.*, 2000). A proteolytic enzyme with specificity for collagen and elastin in connective tissues that work at either the low temperature at which meat is kept or at the high temperature experienced during cooking must be the ideal meattenderizer (Gereld *et al.*, 2000). Papain and bromelain are the commonly used meat tenderizers in industrial level (Ketnawa *et al.*, 2011). The quantity of tenderizer used/applied to improve the satisfactory sensory attributes is the most significant factor. Determination of the correct enzyme dosage for goat meat tenderization is highly applicable for the meat industry. Moreover, the proteolytic enzymes are expensive in terms of cost and it would be ideal to develop a cost-effective tenderizer as a substitute in order to reduce the production cost industrially. Meanwhile, *Bryophyllum pinnatum* commonly *known* as 'never die plant' which was classified under weeds (Oliver, 1983) has its medicinal potential. A recent study identified antimicrobial, antioxidant, antifungal, antiulcer, diuretic, nephro-protective, and anticonvulsant properties of *Bryophyllum pinnatum* (Afzal *et al.*, 2012). The leaves of *Bryophyllum pinnatum* have been traditionally used as a meat tenderizer in Northern Province, Sri Lanka. Even though the *Bryophyllum pinnatum* leaves have been used as a tenderizer, scientific proof is not supported the fact. Therefore this study was aimed to determine the optimum concentration of the *Bryophyllum pinnatum* leaf extract to tenderize the goat meat chunks and to compare its effectiveness of the tenderizing ability with commercial meat tenderizers papain and bromelain on goat meat chunks with the intention of developing cost-effective meat tenderizer.

Materials and Methods

Meat Sample

Hind leg portion of goat carcass was purchased from a retail shop in Jaffna within 2 - 3 hours after slaughtering.

Meat chunks (50±2 g) were cut from the cleaned lot of goat meat (hind leg chump-on) for the experiments.

***Bryophyllum pinnatum* Leaf Extract (Aqueous extraction)**

Fresh leaves of *Bryophyllum pinnatum* were collected from botanical garden of Department of Botany, University of Jaffna, Sri Lanka and were identified and authenticated. The cleaned leaves were cut into small pieces using a sharp knife and 0.5 g, 1.0 g, 1.5 g, and 2.0 g of leaves were taken into the beakers separately and 250 mL of distilled water was added on each beaker and kept at 40- for 24 hours and then filtered to get the leaf extract (Salah deen and Yemiton, 2006) in different concentrations such as 0.2%, 0.4%, 0.6% and 0.8% [weight of leaves (grams)/ volume of distilled water (mL)*100].

Papain and Bromelain Solution

Papain and bromelain were purchased from Analytical Instruments Private Limited (AIPL), Colombo, Sri Lanka. Papain and bromelain solution of 0.2%, 0.4%, 0.6% and 0.8% were prepared based on weight over volume basis [weight of papain or bromelain (g)/volume of distilled water (mL)*100]. Weight of 0.5g, 1.0g, 1.5g, and 2.0g of papain /bromelain was mixed with 250mL of distilled water to prepare 0.2%, 0.4%, 0.6%, and 0.8% of the concentrations respectively.

pH

pH of the goat meat chunks was determined according to A.O.A.C. method (AOAC, 1995), with a Sigma- Aldrich Trans bench top digital pH-meter made in Germany. pH of meat is an indicator of good quality meat (Berri *et al*., 2005).

Rigidity Index

Tenderness degree was rated by rigidity index assessment described by Ionesco *et al.,* 1992.

Thermal Yield (Y_{TP})

Thermal yield was calculated according to the equation: YTP =mf /mi *100. Where: mf - final mass of the sample (after thermal treatment); mi- initial mass of the sample (raw meat).

Sensory Analysis

Sensory analysis was carried out with thirty semi trained panelist with 9-point hedonic scale system where the nine categories range from "dislike extremely" to "like extremely".

Statistical Analysis

Minitab 17 software was used for the statistical analysis. A one-way analysis of variance (ANOVA) was used to assess the significant differences between measured parameters with significant probability value at 0.05 ($p<0.05$). All the experiments were conducted with triplicate samples.

Determination of Optimum Concentration of Tenderizers

Different concentrations of papain solution were prepared (0.2%, 0.4%, 0.6%, and

0.8%). Initial weight of the samples of goat meat chunks was measured. The goat meat chunks were marinated in the prepared papain solution concentration (0.2%, 0.4%, 0.6%, and 0.8%) individually at 4 °C for 24 hours and a control was setup by marinating the goat meat chunks with distilled water at 4 °C for 24 hours. After marination, goat meat chunks were taken out and mixed with 2% (w/w) table salt. Thereafter the meat chunks were subjected for thermal treatment at 15 psi (approximately 120 °C) for 15 minutes by keeping in autoclave. After the thermal treatment, goat meat chunks were allowed to cool at room temperature (29±2 °C) and the pH, rigidity index, and the final weight of the meat chunks were measured and sensory analysis were conducted using Hedonic scales (9 points) with 30 semi-trained panelists. All the experiments were done in triplicates. Statistical analysis was performed using Minitab 17.0 version. The same procedure was repeated with bromelain and *B. pinnatum* leaf extract and the optimum concentration of papain, bromelain and *B. pinnatum* leaf extract were identified.

Comparison of Optimum Concentration of Tenderizers

After determining the optimum concentration of papain, bromelain and *B. pinnatum* leaf extract, the identified concentrations of all the three tenderizers were freshly prepared and the same procedure was carried out with goat meat chunks. Final weight, pH, rigidity index were measured and the sensory evaluation was carried out to compare the tenderizing ability of papain, bromelain and *B. pinnatum* leaf extract.

Results and Discussion

Determination of Optimum Concentration of Tenderizers

pH of the muscle is an indicator of acidity level. The good quality meat generally does have the pH range of 5.4 to 5.7 (Berri *et al.*, 2005). Table 1 shows that the pH of the control sample varies between 5.48 to 5.57 which indicates that the meat used for the experiment was in good quality. All the tenderizer treated meat exhibits higher pH values than the control due to the addition of tenderizers. Similarly Naveena and Mendiratta (2004)observed an increase in pH of beef after the treatment with bromelain. The results were supported by the fact that the increase in the pH of goat meat after papain treatment may be due to its protein degradation action (Narsaiah, 2011) and according to Huang *et al*, (2011) the increase in pH after tenderizer treatment is due to increase loss of free acidic group. pH of all the tenderizer treated meat chunks decreased with increasing concentration of the tenderizers. Bromelain and papain hydrolysis of the meat muscle may result in releasing amino acids that may significantly reduce the pH of the papain and bromelain treated goat meat with increasing concentration (Table 1) (Ketnawa and Rowdkuen, 2011). Result of *Bryophyllum pinnatum* leaf extract follows the same pattern as papain and bromelain (Table 1).

Table 1. pH of the goat meat chunks treated with different concentration of papain, bromelain and *B.pinnatum* leaf extract

Treatment (% g/mL)	Papain	Bromelain	*B.pinnatum* leaf extract
0.2	6.31±0.01 [a]	6.54±0.01 [b]	6.59±0.00 [a]
0.4	6.27±0.01 [b]	6.48±0.00 [a]	6.43±0.00 [b]
0.6	6.20±0.01 [c]	5.98±0.01 [c]	6.34±0.02 [c]
0.8	6.15±0.02 [d]	5.95±0.00 [d]	6.28±0.01 [d]
Control	5.57±0.01 [e]	5.51±0.01 [e]	5.48±0.01 [e]

Mean values followed by different letters within the same column is significantly different at $P< 0.05$.

Table 2. Thermal yield of goat meat chunks treated with different concentration of papain, bromelain, and *B. pinnatum* leaf extract

Thermal yield (%)	Papain	Bromelain	*B.pinnatum* leaf extract
0.2	47.7±0.01 [b]	44.1±0.05 [b]	53.6±0.05 [e]
0.4	46.7±0.01 [c]	42.1±0.08 [c]	53.0±0.08 [d]
0.6	44.5±0.01 [d]	41.7±0.10 [d]	53.2±0.29 [c]
0.8	42.8±0.01 [e]	41.0±0.05 [e]	53.8±0.08 [b]
Control	51.7±0.01 [a]	52.4±0.15 [a]	51.3±0.17 [a]

Mean values followed by different letters within the same column is significantly different at $P< 0.05$.

Thermal yield of papain and bromelain treated meat chunks were significantly decreasing with increasing concentration of the tenderizers. At the same time papain and bromelain treatments show lower thermal yield than the control (Table 2). This attribute is due to the proteolysis of muscle proteins (Pawar *et al*., 2003). Similar pattern was recorded by Nadzriah *et al.*, (2016) where the bromelain treated beef showed higher cooking loss which in other words a lower thermal yield. In case of *B. pinnatum,* the thermal yields of treated samples show higher values than control. It was identified that as water holding capacity increased, moisture loss while heating decreased, resulting in enhanced thermal yield (Sin –Young, 2017). It was stated that phospholipase A2 (PLA2) enzyme activity in muscle lowers the water holding capacity in poultry meat (Velleman, 2000; Chan *et al*., 2011). Study done by Fernandes *et al*., (2019) discovered that the *Bryophyllum pinnatum* leaf extract showed significant inhibitory activity of phospholipase A2 enzyme which might be the reason behind the higher thermal yield of *B. pinnatum* leaf extract treated meat sample.

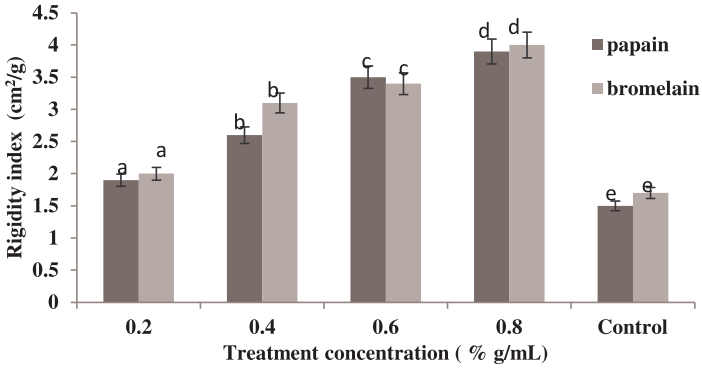

Figure 1. Rigidity index of papain and bromelain treated goat meat chunks
Mean values followed by different letters are significantly different at $P< 0.05$

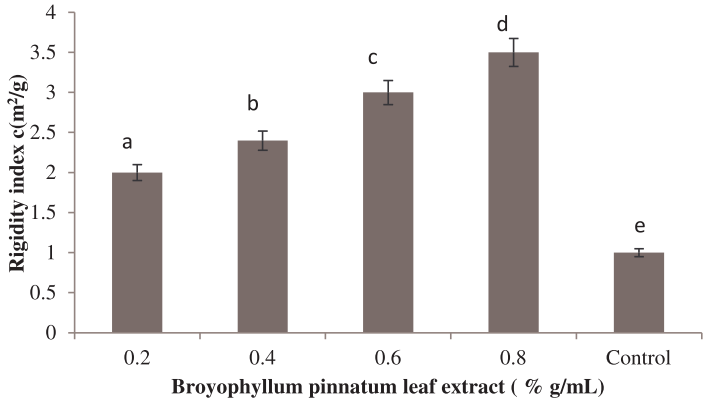

Figure 2. Rigidity index of *B.pinnatum* leaf extract treated goat meat chunks
Mean values followed by different letters are significantly different at $P< 0.05$

Rigidity Index (RI) expresses the deformation level of meat chunks (Ionescu *et al*., 1992). Deformation was comparatively higher in bromelain and papain treated goat meat chunks than the control at the same time rigidity index was significantly increasing with an increasing concentration of papain and bromelain (Figure 1).

The observation was in agreement with the study done by Daniela, (2008) where the increase in level of papain led to a considerable increase in the values of rigidity index. However there is no significant difference between the tenderness of papain and bromelaintrea ted meat samples (Figure 1). Higher deformation in bromelain and papain treated goat meat chunks may be due to loss of physical integrity of muscle fibers and weakening the muscle structure (Daniela *et al*., 2011). The *Bryophyllum pinnatum* leaf extract shows higher rigidity index than control and it is increasing with increasing concentration (Figure 2) which shows the strong tenderizing ability of *B. pinnatum* leaf extract. *B. pinn*atum considered as an ethno medicine for treatment of earache, burns, abscesses, ulcer, insect bites, diarrhea, and lithiasis (Chopra, 1956) and it has vital medicinal properties (Afzal *et al*., 2012). It is revealed that the leaves of medicinal plants could serve asexcellent sources of proteases (Gandhi Shree *et al*., 2018) and the same study found a strong correlation between the protease activity and medicinal application of the plant. Protease treatment is an efficient method used for meat tenderization.

Proteases play a vital role in degrading the structural proteins in the connective tissues and reducing toughness of meat (Arshad *et al*., 2018). Furthermore the *B. pinnatum* leaves consist of considerable amount of calcium and potassium (Nwali *et al*., 2014) and calcium has the ability to activate the endo-protease system calpain and cathepsin in the meat and potassium related to the tenderness of the meat (Tizioto *et al*., 2014).Sutton and Osmond, (1972) recorded the presence of malic acid in *B. pinnatum* leaf and it is revealed that the malic acid marination of beef improve the tenderness of the beef (Wang and Tang, 2018). Presence of protease, malic acid, calcium and potassium in the leaves of *Bryophyllum pinnatum* might be the reason behind its tenderizing ability. Evaluating *Bryophyllum pinnatum* as a meat tenderizer is a novel attempt and the mechanism behind the tenderization and the identification of the particular protease type should be further analyzed.

Table 3: Sensory scores of goat meat treated with different concentration of papain

Treatment (% g/mL)	Juiciness	Tenderness	Flavor	Color	Overall acceptance
Control	5.30±1.25[a]	5.50±0.79[b]	6.16±1.80[a]	7.00±0.60[a]	5.67±0.98[a]
0.2	7.16±1.27[a]	7.83±0.71[a]	6.33±1.37[a]	7.67±0.98[a]	7.83±0.72[b]
0.4	6.33±0.77[a]	6.00±0.61[b]	6.83±1.19[a]	6.17±1.11[b]	5.83±0.39[b]
0.6	5.67±0.98[b]	5.33±0.78[b]	6.66±1.23[a]	5.83±0.93[b]	4.66±0.49[c]
0.8	3.83±0.93[c]	4.50±0.52[c]	6.83±0.93[a]	4.50±0.52[c]	4.16±0.38[c]

Mean values followed by different letters within the same column is significantly different at $P< 0.05$.

Considering the overall acceptance, papain treated goat meat chunks showed positive sensory satisfaction at lower concentrations 0.2% and 0.4% (Table 3). Based on all the sensory attributes (juiciness, tenderness, flavor, colour and overall acceptability), concentration of 0.2% of papain was selected as suitable for tenderization and 0.8% of papain shows significantly lower mean values than all other treatments (Table 3) due to the over tenderization and a creamy surface of goat meat chunks was observed in 0.8% of papain treatment. Overall acceptance of 0.6 % and 0.8 % of papain treatment scored lesser values than the control is due to the over tenderization occurred in higher concentrations of papain. This fact isin agreement with the study done by Ashie *et al.*, (2002) which state that papain tends to over-tenderize the meat surface because it has broad specificity and decomposes connective tissue and myofibrillar proteins indiscriminately, degrading meat quality (Ashie *et al*., 2002). Colour of the 0.6 % and 0.8 % of papain treated sample scored lower values and similar observation was identified by Maria Doneva *et al.*,(2018) who stated that meat color has faded in rabbit meat samples treated with papain and its surface becomes slimy.

Table 4: Sensory scores of goat meat with different concentration of bromelain

Treatment (% g/mL)	Juiciness	Tenderness	Flavor	Color	Overall acceptance
Control	4.25±0.46^{b}	5.17±0.26^{b}	6.50±1.17^{a}	6.75±0.75^{a}	4.67±0.78^{c}
0.2	5.75±0.45^{a}	7.50±1.17^{a}	6.42±1.08^{a}	7.08±0.79^{a}	8.33±0.77^{a}
0.4	4.50±0.52^{b}	5.16±0.94^{b}	6.92±0.66^{a}	4.33±0.77 ^{b}	5.67±1.15^{b}
0.6	4.00±1.27^{b}	3.83±0.71^{c}	6.42±1.08^{a}	3.66±0.49 ^{b}	3.17±0.71^{d}
0.8	2.75±0.87^{c}	3.00±0.60^{c}	6.58±0.79^{a}	3.68±0.67^{c}	2.83±0.71^{d}

Mean values followed by different letters within the same column is significantly different at $P< 0.05$.

With regard to the all sensory attributes (juiciness, tenderness, flavor, colour and overall acceptability), 0.2% of bromelain treatment was selected as an optimum concentration to tenderize the meat as it scores significantly higher mean value than other treatment concentrations and the control (Table 4). Higher concentration of bromelain especially 0.6% and 0.8% scores significantly lower mean values in terms of juiciness, tenderness, colour and overall acceptability than the control (Table 4) samples. This attribute may be due to the over tenderization which caused a creamy surface on goat meat chunks in those particular treatments.

Table 5: Sensory scores of goat meat treated with *Bryophyllum pinnatum* leaf extract

Treatment (% g/mL)	Juiciness	Tenderness	Flavor	Color	Overall acceptance
Control	6.60±1.79^{a}	5.15±1.84^{c}	6.65±0.36^{a}	5.90±1.51^{a}	4.70±1.72^{c}
0.2	5.90±0.45^{a}	5.10±1.59^{c}	6.75±0.91^{a}	6.60±1.57^{a}	6.30±1.17^{b}
0.4	6.00±1.84^{a}	6.20±1.19^{b}	6.60±1.05^{a}	6.45±1.70^{a}	5.65±1.75^{c}
0.6	7.00±0.78^{a}	7.00±1.08^{a}	6.80±0.41^{a}	6.15±1.72^{a}	7.45±0.76^{a}
0.8	6.90± 0.71^{a}	7.75±0.63^{a}	6.75±1.12^{a}	5.95±1.50^{a}	7.50±0.89^{a}

Mean values followed by different letters within the same column is significantly different at $P< 0.05$.

Based on the overall acceptance of sensory results, 0.6% and 0.8% of *Bryophyllum pinnatum* leaf extracts exhibited a higher mean values (Table 5), thus there were no significant difference between the mean values of concentration 0.6% and 0.8% treated meat chunks , the lower concentration 0.6% was selected as an optimum concentration to tenderize the goat meat.

Comparison of optimum concentration of papain, bromelain and B.pinnatum leaf extract on goat meat chunks

All the meat chunks treated with tenderizers show significantly lower pH than the control (Table 6), as it discussed above(Table 1) might be due to the release of amino acids (Ketnawa *et al.*, 2011) and the significantly higher thermal yield was observed in *Bryophyllum pinnatum* treated goat meat than papain and bromelain treated goat meat chunks. Thermal yield of papain and bromelain exhibit lower values than the control might be due to the degradation of muscle fibers in other words proteolysis of muscle fibers (Pawar *et al*., 2003). Percentage of bound water is lower in papain and bromelain treated meat sample as papain and bromelain has a slightly destructive action on muscle tissue and the keeping ability of water by the muscle tissue is thus limited which may reduce the thermal yield of papain and bromelain (Daniella *et al*., 2011). *B. pinnatum* leaf extract exhibits higher thermal yield than all other treatments including control (Table 6). This attribute is due to the inhibitory activity of *B. pinnatum* leaf extract towards the phospholipase A2 enzyme (Fernandes *et al*., 2019) which lowers the water holding capacity of the meat(Velleman, 2000; Chan *et al*., 2011) and thereby increasing the thermal yield

Table 6: Comparison of pH and thermal yield of goat meat treated with different tenderizers

Treatment (% g/mL)	pH after the treatment	Thermal yield (%)
Papain (0.2)	5.67 ± 0.00^{c}	49.5 ± 0.05^{c}
Bromelain (0.2)	5.46 ± 0.01^{a}	48.3 ± 0.05^{d}
***B. pinnatum* leaf extract (0.6)**	5.51 ± 0.01^{b}	53.0 ± 0.15^{a}
Control	5.64 ± 0.00^{d}	51.9 ± 0.14^{b}

Mean values followed by different letters within the same column is significantly different at $P< 0.05$.

as discussed in Table 2. Moreover potassium and calcium are the major minerals identified in the *B. pinnatum* leaves (Nwali *et al*., 2014) and the potassium ions are present in the cationic hofmeister series which related to efficient stabilization of the proteins in the system and thereby improving the water holding capacity of the meat (Pospiech and Montowska, 2011).

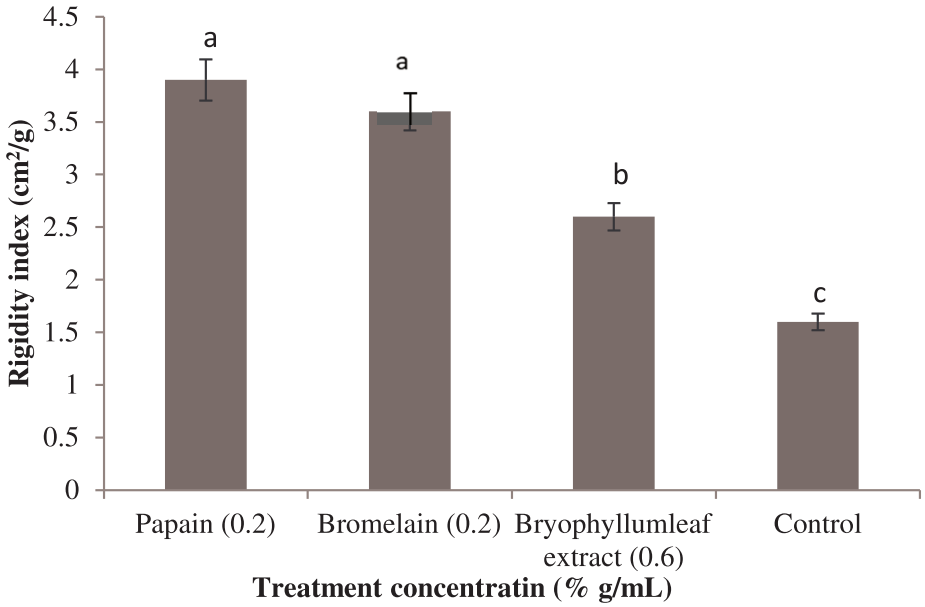

Figure 3: Rigidity index of goat meat treated with different tenderizers

Mean values Followed by different letters are significantly different at $P< 0.05$

Papain and bromelain treated goat meat scored significantly higher rigidity index or the higher deformation than other treatments (Figure 3) and there were no significant difference between the tenderizing degree of papain and bromelain on goat meat chunks (Figure 3). *B. pinnatum* leaf extract exhibited comparatively lower deformation than papain and bromelain but the deformation level is higher than the control (Figure 3). Rigidity index of *B. pinnatum* leaf extract treated meat (2.6 cm^2g) is nearly 1.6 times higher than the control (1.6 cm^2g) whereas the papain (3.9 cm^2g) and bromelain (3.6 cm^2g) treated samples scored nearly twice a time greater value. Rigidity index is an instrumental assessment to measure the tenderness. Figure 3 illustrates that *B. pinnatum* strongly tenderize the meat and it can be considered as a meat tenderizer. Meat tenderness is highly related to sensory satisfaction of the consumers, therefore sensory analysis scores should be taken to consideration with instrumental method.

Table 7: Sensory scores of goat meat treated with different tenderizers

Treatment (% g/mL)	Juiciness	Tenderness	Flavor	Color	Overall acceptance
Papain (0.2)	6.90±0.30^{a}	7.60±0.50^{a}	7.00±1.12^{a}	3.40±1.23^{c}	7.05±1.19^{a}
Bromelain (0.2)	6.70±0.65^{a}	7.35±0.81^{a}	7.00±1.12^{a}	3.20±0.76^{c}	6.80±1.19^{a}
***B.pinnatum* leaf extract (0.6)**	6.10±0.55^{b}	6.00±0.65^{b}	6.80±1.00^{a}	7.40±0.05^{a}	6.10±1.07^{b}
Control	4.40±0.68^{c}	4.65±0.48^{c}	6.50±1.39^{a}	5.60±0.50^{b}	4.45±1.27^{c}

Mean values followed by different letters within the same column is significantly different at $P< 0.05$.

Based on the sensory scores of overall acceptability, 0.2% of papain and 0.2% of bromelain concentrations scored well and there were no significant difference between these two proteolytic enzymes on the sensory attributes (juiciness, colour, tenderness, flavor, and overall acceptance) of goat meat chunks (Table 7). Even though *B. pinnatum* leaf extract scored significantly lower values than commercial tenderizers (papain and bromelain) in terms of juiciness, tenderness, flavor and overall acceptability, the mean value of overall acceptance of leaf extract was above average (Like slightly) and specifically in the sensory attribute of colour, the *B. pinnatum* leaf extract performed well than the papain and bromelain treatments (Table 7). Colour fading due to papain treatment in rabbit meat was experimentally experienced by Maria Doneva *et al* (2018). It can be said that *B. pinnatum* leaf extract treated sample scored nearly 1.3 times greater value than the control and papain and bromelain scored 1.5 times greater values in terms of overall acceptability. A similar study done with pomegranate seed powder as a tenderizer, revealed that tenderization of goat meat with pomegranate seed powder improved the textural properties marginally with slight adverse colour change (Narsaiah *et al*., 2011).

Conclusions

Commercial meat tenderizers Papain and bromelain at 0.2% (g/mL), and *Bryophyllum pinnatum* leaf extract at 0.6% (g/mL) were chosen as suitable concentrations to tenderize the goat meat chunk under the conditions selected in this study. Papain and bromelain scored

significantly higher sensory satisfaction than *Bryophyllum pinnatum* leaf extract in overall acceptance. Even though comparatively *Bryophyllum* leaf extract is inferior to commercial meat tenderizers, the sensory score mean value was above average (6.10, Like slightly) in terms of overall acceptability. Moreover, *B. pinnatum* leaf extract was favorable than the commercial tenderizers specifically in the sensory attribute of colour and the thermal yield of goat meat. Therefore, it is recommended to use *B. pinnatum* leaf extract (0.6% (g/mL) for marinating of goat meat as a cost-effective approach instead of using high cost commercial meat tenderizers papain and bromelain. The protease type present in *B. pinnatum* leaf extract or the real mechanism behind the tenderizing ability of *B. pinnatum* leaf extract and its potential application in meat recovery from the bones need to be investigated.

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