



## Physical-chemical quality of ram and bull meat as affected by ginger extract

Ayad Baker Mahmmod, Arazw Abdula Hama and Hemn Ghazi Zahir

Department of Animal production, College of Agriculture, University of Sulaimany, Sulaimani, Iraq

### Abstract

This study was carried out to examine the effects of different concentration of Ginger (*Zingiber officinale*) at the rate of 0, 3 and 6% concentration on physical (cooking loss, drip loss and water holding capacity), chemical characteristics (Thiobarbituric acid and tyrosine/tryptophan index) and sensory evaluation (colour, flavour and aroma, tenderness, juiciness and overall acceptability) of ram and bull meat. The muscles pieces (500 g) were divided into three groups, marinated with different concentrations (0, 3 and 6% V/W) of ginger extract (GE) and stored at -18°C for two weeks until analysis. A significant decrease ( $P<0.01$ ) in cooking loss, drip loss and an increase in water holding capacity were observed with the increase of ginger extract concentration compared to 0% GE treatment. Thiobarbituric acid (TBA) value decreased ( $P<0.01$ ) with increase ginger extract concentration for ram and bull muscles. The 6% ginger extract treatment prevented lipid oxidation, resulted in the lowest TBA value compared with 3 and 0% GE treatments. Further 6% ginger extract treatment recorded the highest total tyrosine/tryptophan index, non-protein tyrosine/tryptophan index and protein tyrosine/tryptophan index. The results showed that ram meat exhibited higher ( $P<0.01$ ) tenderness, juiciness and overall acceptability at 6 and 3% compared to 0% GE treatment. These results suggested that 6% crude ginger rhizome extract can be effectively utilized to tenderize tough ram and bull meats without adversely affecting other meat quality parameters.

**Keywords:** Meat quality; ginger extract; ram and bull

**To cite this article:** Mahmmod AB, AA Hama and HG Zahir, 2014. Physical-chemical quality of ram and bull meat as affected by ginger extract. Res. Opin. Anim. Vet. Sci., 4(10): 550-555.

### Introduction

Meat qualities like tenderness, juiciness, colour and flavour have been considered as the most important palatability traits by consumers (Lawrie, 1998). Among these traits, tenderness has been rated as the most important meat quality characteristic (Miller et al., 2001). Therefore, improving customer satisfaction and maintaining the consistency of meat products and eliminating the variability in meat tenderness have been a major concern and challenge for the meat industry (Behrends et al., 2005). The technologies used to improve meat tenderness have achieved success to various degrees, which included post-mortem ageing (Jayasooriya et al., 2007), mechanical tenderization (Anna et al., 2007; Bowker et al., 2007), electrical stimulation (Hwang et al., 2003; Hopkins et al., 2006) and ionic chemical solution (Koohmaraie et al., 1989; Hunt et al., 2003). Use of proteolytic enzymes for

tenderization of meat is common throughout the world. Proteolytic enzymes derived from plants such as papain, bromelain and ficin have been widely used as meat tenderizers (Lewis and Luh, 1988; Ashie et al., 2002; Sinku et al., 2003). However, these enzymes often degrade the texture of meat due to their broad substrate specificity leading to unfavourable taste or over tenderization due to unequal distribution (Cronlund and Woychik, 1987). Although several microbial elastases and collagenases have also been isolated and characterized, yet these enzymes are not successful in meat products due to safety problems or other harmful effects (Miller et al., 1989).

A promising protease “Zingibain” isolated from *Zingiber officinale roscoe* (Ginger rhizome) has been reported to have proteolytic activity. Its proteolytic activity on collagen was found to be many folds greater than actomyosin, and the combined proteolysis of these two muscle proteins improve the tenderness of meat

**\*Corresponding author:** Ayad Baker Mahmmod, Department of Animal production, College of Agriculture, University of Sulaimany, Sulaimani, Iraq

(Thompson et al., 1973). Ginger rhizome is used primarily as flavoring agent for bakery products and as a sausage seasoning. Its utilization as a meat tenderizing agent is not fully appreciated and the literature available is limited.

Plant enzymes with tenderizing capacity are particularly important in applications involving muscles rich in connective tissue. These muscles often make up the cheaper carcass cuts and the tenderizing effect of these enzymes offers a commercially important means of upgrading this tissue. Therefore, with a view to upgrading low value meat cuts (biceps femoris muscle) using easily sourced ingredients, the effect of different concentrations of ginger extract on physical, chemical, and sensory properties of ram and bull meat was investigated.

## Materials and Methods

Fresh ginger rhizome was purchased from a local market. The rhizome was peeled, sliced and blended with equal quantity of chilled distilled water for 1–2 min. The slurry was then filtered with four layers of muslin cloth and filtrate was collected as the crude extract. The *Biceps femoris* muscles of carcass were obtained after slaughter, from local slaughter units. After chilling for 24 h at  $4\pm 1^\circ\text{C}$ , the muscles were cut into 3 uniform  $\text{cm}^3$  sized chunks. Meat chunks were randomly divided into three groups (500 g each) and marinated with different concentrations (0, 3 and 6% v/w) of ginger extract. The required volume of ginger extract (GE) was diluted with distilled water and the mixture was sprayed at 15% v/w of meat chunks (15 ml/100 g meat). Thus it comprises three different treatments:

- 1: 0% Control: 15 ml distilled water
- 2: 3% (v/w) GE: 3 ml GE+12 ml distilled water
- 3: 6% (v/w) GE: 6 ml GE+9 ml distilled water

After thorough mixing by hand, the chunks were placed in polyethylene bags and held at  $4\pm 1^\circ\text{C}$  for 48 h and then stored at  $-18^\circ\text{C}$  for two weeks until analysis.

### Physical tests

**Cooking loss:** Cooking loss was determined according to the method of Murphy and Zerby (2004). Muscle samples (20 gm) were placed in an open aluminium box and cooked for 8.5 min in oven pre-heated to  $176^\circ\text{C}$  to an internal temperature of  $70^\circ\text{C}$ .

After cooking, the samples were dried with a paper towel. Each sample was cooled for 30 min and the weight was measured. The cooking weight was subtracted from the raw weight to calculate cooking loss. The cooking loss was calculated by the following formula:

$$\text{Cooking loss \%} = \frac{\text{Raw sample weight} - \text{cooked sample weight}}{\text{Raw sample weight}} \times 100$$

**Drip loss:** Drip loss was determined according to the method of Nam et al. (2000). Frozen muscle samples were weighed, and then thawed for 24 h at  $4^\circ\text{C}$ . Meat samples were dried with a paper towel and again weighed. The drip loss was calculated by the following formula:

$$\text{Drip loss \%} = \frac{\text{Frozen sample weight} - \text{thawed sample weight}}{\text{Frozen sample weight}} \times 100$$

### Water holding capacity (WHC)

Water holding capacity (WHC) was determined according to the method of Wardlaw et al. (1973). Briefly, 20 gm of minced muscle sample was placed in centrifuge tube containing 30 ml of 0.6M NaCl and was stirred with glass rod for 1 min. The tube was kept at refrigeration temperature ( $4^\circ\text{C}$ ) for 15 min, stirred again and centrifuged at  $2806.1 \times g$  ( $4^\circ\text{C}$ ) for 15 min.

The supernatant was measured and amount of water retained by samples was expressed in percentage. The WHC was reported as ml of 0.6 M NaCl per 100 g of muscle according to the following formula:

$$\text{WHC \%} = \frac{\text{Initial solution weight} - \text{final solution weight}}{\text{sample weight (gm)}} \times 100$$

### Chemical test

**Thiobarbituric acid (TBA) value:** The TBA was determined according to the method described by Witte et al. (1970). 20 g of the muscle was blended with 50 ml of cold solution containing 20% trichloroacetic acid (TCA) in 2M phosphoric acid. The resulting slurry was transferred to a 100 ml volumetric flask with 40 ml distilled water. The sample was diluted to 100 ml with distilled water and homogenized by shaking. A 50 ml protein was filtered through Whatman No.1 filter paper. 5 ml of filtrate was transferred to a test tube followed by 5 ml of fresh thiobarbituric acid (TBA) (0.005M in distilled water). The blank was prepared by mixing 5 ml of distilled water with 5 ml of TBA. The solution mixture was kept in the dark for 15-17 h at room temperature to develop the colour reaction. The absorbance was read at 530 nm by using spectrophotometer (Shimadzu, Japan). The TBA value was expressed as mg malonaldehyde (MDA)/kg muscle, which was calculated by multiplying the absorbance (A) by 5.2 factors as follows:

$$\text{TBA value (mg MDA/kg muscle)} = A_{530} \times 5.2$$

**Tyrosine/Tryptophane index:** Total of Tyrosine/Tryptophane index was determined according to the method described of El-Badawi et al. (1964). 50 ml of

**Table 1: Effect of different concentrations of crude ginger extract on cooking loss, drip loss and water holding capacity (WHC) percentages in *biceps femoris* muscle (BF) of ram and bull (Means  $\pm$  S.E)**

Treatments	Cooking loss (%)		Drip loss (%)		WHC (%)	
	Ram	Bull	Ram	Bull	Ram	Bull
T1 (0% GE)	52.92 $\pm$ 0.04 <sup>a</sup>	57.01 $\pm$ 0.04 <sup>a</sup>	4.15 $\pm$ 0.02 <sup>a</sup>	4.65 $\pm$ 0.08 <sup>a</sup>	43.27 $\pm$ 0.08 <sup>b</sup>	41.24 $\pm$ 0.03 <sup>a</sup>
T2 (3% GE)	48.82 $\pm$ 0.00 <sup>b</sup>	50.95 $\pm$ 0.02 <sup>b</sup>	3.7 $\pm$ 0.11 <sup>b</sup>	4.15 $\pm$ 0.14 <sup>b</sup>	51.24 $\pm$ 0.18 <sup>a</sup>	49.27 $\pm$ 0.08 <sup>b</sup>
T3 (6% GE)	48.11 $\pm$ 0.00 <sup>c</sup>	49.96 $\pm$ 0.020 <sup>c</sup>	3.5 $\pm$ 0.23 <sup>c</sup>	3.75 $\pm$ 0.14 <sup>b</sup>	51.69 $\pm$ 0.32 <sup>a</sup>	50.49 $\pm$ 0.05 <sup>c</sup>

<sup>abc</sup>Means within the same column for each trait with different letters are significantly different (P<0.01)

distilled water was mixed with 10 g of minced muscle. The mixture was filtered through Whatman No.1 filter paper. The filtrate was diluted with distilled water at ratio 1:1 (v/v).

The absorbance was measured at 280 nm using spectrophotometer. Non protein Tyrosin/Tryptophan index was estimated by adding equal volume of 15% TCA to the filtrate at ratio 1:1 (v/v) for precipitation of proteins, and then the mixture was filtered through Whatman No.1 filter paper.

The filtrate was used to estimate the absorbance at 280 nm. The protein Tyrosin/Tryptophan index was determined by subtracting tyrosine/tryptophane index value from total Tyrosin/Tryptophane value.

### Sensory evaluation

Cooked products were served to 7 experienced panel members with previous experience. Panellists were presented with four randomly coded samples. An 8 point descriptive scale (1=extremely poor, extremely undesirable, extremely dry, extremely tough and extremely unpalatable, respectively, and 8=excellent, extremely desirable, extremely juicy, extremely tender and extremely palatable, respectively) was used to evaluate appearance, flavour, juiciness, tenderness and overall palatability. Panellists were required to cleanse their palates between samples with water (Keeton 1983).

### Statistical analysis

The data were analyzed by analysis of variance (CRD) design using SAS program (SAS, 2010) and significance between means was determined using Duncan's multiple range test (Duncan, 1955).

## Results and Discussion

### Cooking loss, drip loss and water holding capacity

There were significant differences (P<0.01) among treatments in cooking loss for both ram and bull muscles (Table 1). Muscles marinated in 6% ginger extract (GE) had lower cooking loss compared with 3% GE and 0% GE treatment. About drip loss, there were significant differences among treatments. The 6% GE treatment recorded lower drip loss while 0% GE treatment recorded higher drip loss (Table 1). There were significant differences (P<0.01) between treatments in WHC (Table 1). 6% GE treatment resulted

**Table 2: Effect of different concentrations of crude ginger extract on thiobarbituric acid (TBA) (mg malonaldehyde MDA/kg meat) in *biceps femoris* muscle of ram and bull (Means  $\pm$  S.E)**

Treatments	TBA	
	Ram	Bull
T1 (0% GE)	1.63 $\pm$ 0.01 <sup>a</sup>	1.72 $\pm$ 0.01 <sup>a</sup>
T2 (3% GE)	1.27 $\pm$ 0.00 <sup>b</sup>	1.30 $\pm$ 0.00 <sup>b</sup>
T3 (6% GE)	1.14 $\pm$ 0.02 <sup>c</sup>	1.20 $\pm$ 0.00 <sup>c</sup>

<sup>abc</sup>Means within the same column for each trait with different letters are significantly different (P<0.01)

in higher WHC for ram and bull muscles compared with 3 and 0% GE treatments.

These results are probably due to the phenolic components in the plants extracts which improve proteins and meat moisture and prevented water loss, thereby resulted in more moisture retention (Romans and Ziegler, 1977; Saleh, 2007). The present results are similar to the findings of previous reports which showed stabilizing effect on thawing and cooking loss and other meat quality with increase ginger extract concentration (Naveena and Mendiratta, 2004; Al-Temimi and Abu-Almaaly, 2011).

### Thiobarbituric acid (TBA)

The results presented in Table 2 showed a significant difference (P<0.01) among treatments in TBA values in the ram and bull muscles. The TBA values decreased at the rate of 6% GE compared with 3 and 0%. TBA values are considered as an indicator of lipid peroxidation in meat products during storage (Brunton et al., 2000). The results of present study may be related to the antioxidant characteristics of GE, which prevented lipid oxidation in the phospholipids-rich membranes of meat (Lee et al., 1986; Kim and Lee, 1995; Mendiratta et al., 2000).

### Tyrosine/tryptophan index

The results showed that 6% GE caused a significant increase in Tyrosine/tryptophan index, Non-protein tyrosine/tryptophan index and Protein tyrosine/tryptophan index in muscle of ram and bull. Meat treated with plant enzymes increase liberation of aromatic amino acids like tyrosine and tryptophan (Hassan, 2002). Ginger extract has a powerful enzymatic activity towards the muscle fibre and may result in extensive degradation of meat (Mansour and Khalil, 2000; Zhao et al., 2012; Zochowska-Kujawska et al., 2013).

**Table 3: Effect of different concentrations of crude ginger extract (GE) treatments on total tyrosine/tryptophan index, non-Protein tyrosine/tryptophan index and protein tyrosine/tryptophan index in *biceps femoris* muscle of ram and bull (Means  $\pm$  S.E)**

Treat.	Tyrosine/tryptophan index		Non-proteintyrosine/tryptophan index		Protein tyrosine/tryptophan index	
	Ram	Bull	Ram	Bull	Ram	Bull
T1 (0% GE)	5.51 $\pm$ 0.00 <sup>c</sup>	5.27 $\pm$ 0.04 <sup>c</sup>	1.21 $\pm$ 0.00 <sup>c</sup>	1.14 $\pm$ 0.00 <sup>c</sup>	4.29 $\pm$ 0.00 <sup>c</sup>	4.13 $\pm$ 0.04 <sup>c</sup>
T2 (3% GE)	6.57 $\pm$ 0.01 <sup>b</sup>	6.39 $\pm$ 0.00 <sup>b</sup>	1.50 $\pm$ 0.00 <sup>b</sup>	1.40 $\pm$ 0.00 <sup>b</sup>	5.07 $\pm$ 0.01 <sup>b</sup>	4.99 $\pm$ 0.00 <sup>b</sup>
T3 (6% GE)	6.71 $\pm$ 0.00 <sup>a</sup>	6.57 $\pm$ 0.01 <sup>a</sup>	1.60 $\pm$ 0.00 <sup>a</sup>	1.50 $\pm$ 0.00 <sup>a</sup>	5.11 $\pm$ 0.01 <sup>a</sup>	5.06 $\pm$ 0.01 <sup>a</sup>

<sup>abc</sup>Means within the same column for each trait with different letters are significantly different (P<0.01)

**Table 4: Effect of different concentrations of crude ginger extract treatment on sensory evaluation scores in *biceps femoris* muscle (BF) of ram and bull (Means  $\pm$  S.E)**

Treat.	Colour		Flavour and aroma		Tenderness		Juiciness		Overall acceptability	
	Ram	Bull	Ram	Bull	Ram	Bull	Ram	Bull	Ram	Bull
T1 (0% GE)	2.75 $\pm$ 0.02 <sup>a</sup>	2.75 $\pm$ 0.02 <sup>a</sup>	2.5 $\pm$ 0.57 <sup>b</sup>	2.25 $\pm$ 0.05 <sup>b</sup>	2.50 $\pm$ 0.28 <sup>b</sup>	2.25 $\pm$ 0.02 <sup>a</sup>	2.50 $\pm$ 0.28 <sup>b</sup>	2.50 $\pm$ 0.02 <sup>a</sup>	2.50 $\pm$ 0.28 <sup>b</sup>	2.75 $\pm$ 0.25 <sup>a</sup>
T2 (3% GE)	3.50 $\pm$ 0.28 <sup>a</sup>	3.25 $\pm$ 0.25 <sup>a</sup>	3.5 $\pm$ 0.28 <sup>b</sup>	3.25 $\pm$ 0.25 <sup>a</sup>	3.50 $\pm$ 0.28 <sup>a</sup>	3.00 $\pm$ 0.00 <sup>a</sup>	3.50 $\pm$ 0.28 <sup>a</sup>	3.00 $\pm$ 0.00 <sup>a</sup>	3.25 $\pm$ 0.25 <sup>ab</sup>	3.00 $\pm$ 0.00 <sup>a</sup>
T3 (6% GE)	3.50 $\pm$ 0.28 <sup>a</sup>	3.25 $\pm$ 0.25 <sup>a</sup>	3.50 $\pm$ 0.25 <sup>a</sup>	3.25 $\pm$ 0.25 <sup>a</sup>	4.00 $\pm$ 0.00 <sup>a</sup>	3.25 $\pm$ 0.25 <sup>a</sup>	3.75 $\pm$ 0.25 <sup>a</sup>	3.00 $\pm$ 0.00 <sup>a</sup>	3.50 $\pm$ 0.28 <sup>a</sup>	3.25 $\pm$ 0.25 <sup>a</sup>

<sup>abc</sup>Means within the same column for each trait with different letters are significantly different (P<0.01)

### Sensory evaluation

Table 4 showed significant differences (P<0.01) among treatments in flavour and aroma for ram and bull muscles. The 3 and 6% ginger extract (GE) treatment resulted in higher scores for both flavour and aroma than 0% GE treatment. This result may be due to the presence of active compounds (phenols and vitamin C) in ginger extract, which can retard lipid oxidation and maintain desired meat flavour (Lee et al., 1986; Mustafa et al., 1993).

The results in Table 4 showed that ram meat exhibited higher (P<0.01) tenderness, juiciness and overall acceptability at 6 and 3% compared to 0% GE treatment. In general, the sensory quality of ram muscle expressed superior quality than bull muscle which may be co-related to the difference in chemical composition of meat (Aberle et al., 2001), size of the muscle fibre and connective tissue (Aberle et al., 2001) in the two difference species. The improvement in tenderness and juiciness as a result of GE treatment may be due to proteolytic activity of ginger extract, enhancing meat ability to bind water and decreasing exudative liquid loss during thawing (Al-Rubeii et al., 2009; Sallam et al., 2010; Zochowska-Kujawska et al., 2013).

The results of improved sensory scores using ginger extract have been reported previously (Mendiratta et al., 2000; Al-Temimi and Abu-Almaaly, 2011; Zochowska-Kujawska et al., 2013).

### Conclusion

This study has shown that 6% crude ginger rhizome extract can be effectively utilized to tenderize tough ram and bull meats without adversely affecting other meat quality parameters.

### References

Aberle, E.D., Forrest, J.C., Gerrard, D.E. and Mills, E.W. 2001. Principles of meat Science. 4th ed. Kendall/Hunt Publishing Company, IA.

Al-Rubeii, A., Al-Kaisey, M.S., M.T. and Khadom, M.J. 2009. Comparative of the antioxidant potential of natural plants with synthetic antioxidants during cold storage of ground beef meat. *Alex Journal of Food Science and Technology*, 6: 1-16.

Al-Temimi, S.S. and Abu-Almaaly, R.A. 2011. The Effects of Ginger (*Zingibarofficinale*) on physical properties and the Sensory Evaluation of beef burger. *Iraq Journal for Market Research and Consumer Protection*, 3: 31-52.

Anna, A.M., Lakshmanan, V. Radha, K. Singh, R.P. Mendiratta, S.K. and Anjaneyulu, A.S.R. 2007. Effect of blade tenderization and sodium bicarbonate on quality of buffalo rumen meat. *Journal of Food Science and Technology*, 44: 437-439.

Ashie, I.N.A., Sorensen T.L. and Nielsen, P.M. 2002. Effects of papain and a microbial enzyme on meat proteins and beef tenderness. *Journal of Food Science*, 67: 2138-2142.

Behrends, J.M., Goodson, K.J., Koohmaraie, M. Shackelford, S.D. Wheeler, T.L. Morgan, W.W. Reagan, J.O. Gwartney, B.L. Wise J.W. and Savell J.W. 2005. Beef customer satisfaction: factors affecting consumer evaluation of calcium chloride-injected top sirloin steaks when given instructions for preparation, *Journal of Animal Science*, 83: 2869-2875.

Bowker, B.C., Liu, M.N. Solomon, M.B. Eastridge, J.S. Fahrenholz, T.M. and Vinyard, B. 2007. Effects of hydrodynamic pressure processing and blade tenderization on intramuscular collagen and tenderness-related protein characteristics of top rounds from Brahman cattle. *Journal of Muscle Foods*, 18: 35-55.

Brunton, N.P., Cronin, D.A. Monahan F.J. and Durcan, R. 2000. A comparison of solid phase microextraction (SPME) fibres for measurement of

- hexanal and pentanal in cooked turkey. *Food Chemistry*, 68: 339-345.
- Cronlund, A.L. and Woychik, J.H. 1987. Solubilization of collagen in restructured beef with collagenase and  $\alpha$ -amylase. *Journal of Food Science*, 52: 857-860.
- Duncan, D.B. 1955. Multiple ranges and multiple F tests. *Biometrics*, 1:42.
- El-Badawi, A.A., Angiemar, A.F. and Gain, R.E. 1964. Effect of soaking in water thermal enzyme in activation irradiation on the textural of beef. *Food Technology*, 18: 149-155.
- Hassan, O.F. A. 2002. Using calotropisprocera protease in tenderization of aged ewe meats. M.Sc. Thesis, Collage of Agriculture, University of Baghdad.
- Hopkins, D.L., Shaw, F.D. Baud, S. and Walker, P.J. 2006. Electrical currents applied to lamb carcasses effects on blood release and meat quality. *Australian Journal of Experimental Agriculture*, 46: 885-889.
- Hunt, M.C., Schoenbeck, J.J. Yancey, E.J. Dikeman, M.E. Loughin, T.M. and Addis, P.B. 2003. Effects of post exsanguination vascular infusion of carcasses with calcium chloride or a solution of saccharides, sodium chloride, and phosphates on beef display-colour stability. *Journal of Animal Science*, 81: 669-675.
- Hwang, I.H., Lee, J.M. and Thompson, J.M. 2003. The role of electrical stimulation in meat tenderness. *Food Science Biotechnology*, 12: 191-197.
- Jayasooriya, S.D., Torley, P.J. D'Arcy, B.R. and Bhandari, B.R. 2007. Effect of High power ultrasound and ageing on the physical properties of bovine semitendinosus and longissimus muscles. *Meat Science*, 75: 628-639.
- Keeton, J.T. 1983. Effect of fat and NaCl/phosphate levels on the chemical and sensory properties of pork patties. *Journal of Food Science*, 48: 878-881.
- Kim, K.J. and Lee, Y.B. 1995. Effect of ginger rhizome extract on tenderness and shelf life of pre-cooked lean beef. *Asian Australian Journal of Animal Science*, 8: 343-346.
- Koohmaraie, M., Crouse, J.D. and Mersmann, H.J. 1989. Acceleration of post- mortem tenderization in ovine carcasses through infusion of calcium chloride: effect of concentration and ionic strength. *Journal of Animal Science*, 67: 934-942.
- Lawrie, R.A. 1998. Lawrie's meat science. 6th Ed. Woodhead Publishing Ltd. England.
- Lee, Y.B., Sehnert, D.J. and Ashmore, C.R. 1986. Antioxidant property in ginger rhizome and its applications to meat products. *Journal of Food Science*, 51: 20-23.
- Lewis, D.A. and Luh, B.S. 1988. Application of actinidin from kiwifruit to eat tenderization and characterization of beef muscle protein hydrolysis, *Journal of Food Biochemistry*, 12: 147-158.
- Mansour, E.H. and Khalil, A.H. 2000. Evaluation of antioxidant activity of some plant extracts and their application to ground beef patties. *Food Chemistry*, 69: 135- 141.
- Meller, A.J., Strange, E.D. and Whiting, R.C. 1989. Improved tenderness of restructured beefsteaks by microbial collagenase derived from vibrio B-30. *Journal of Food Science*, 54: 855-857.
- Mendiratta, S.K., Anjaneyulu, A.S.R., Lakshmanan, V., Naveena, B.M. and Bisht, G.S. 2000. Tenderizing and antioxidant effect of ginger extract on sheep meat. *Journal of Food Science and Technology*, 37: 565-570.
- Miller, A.J., Strange, E.D. and Whiting, R.C. 1989. Improved tenderness of restructured beefsteaks by microbial collagenase derived from vibrio B-30. *Journal of Food Science*, 54: 855-857.
- Miller, M. F., Carr, M. F. Ramsey, C. B. Crockett K. L. and Hoover L. C. 2001. Consumer thresholds for establishing the value of beef tenderness, *Journal of Food Science*, 79: 3062-3068.
- Murphy, M.A. and Zerby, H.N. 2004. Pre-rigor infusion of lamb with sodium chloride, phosphate and dextrose solutions to improve tenderness. *Meat Science*, 66: 343-349.
- Mustafa, T., Srivastava, K.C. and Jensen, K.B. 1993. Drug Development Report 9: Pharmacology of ginger, Zingiberofficinale. *Journal of Drug Development*, 6: 25-39.
- Nam, J., Park, H., Songa, C.K., Kim, D.G., Moon, Y.H. and Jung, I.C. 2000. Effect of freezing and re-freezing treatment on chicken meat quality. *Food Science*, 20: 222-229.
- Naveena, B.M. and Mendiratta, S.K. 2004. The tenderization of buffalo meat using ginger extract. *Journal of Muscle Foods*, 15: 235-244.
- Romans, J.R. and Ziegler, P.T. 1977. *The Meat We Eat*. The Interstate Printers and Publishers, Inc., U.S.A.
- Sallam, K., Ishioroshi, M. and Samejima, K. 2010. Antioxidant and antimicrobial effects of ginger in chicken sausage. *Meat Science*, 37: 849-855.
- Saleh, H.H. 2007. The influence of vitamin E, C, their combination and grape seed extract and juice concentrate on some quality characteristics of meat and adipose tissue of aged ewes. Ph.D Thesis. Animal Resources, College of Agriculture, University of Baghdad.
- SAS Users Guide, 2010. *SAS Inst., Inc. Cary, NC*.
- Sinku, R.P., Prasad, R.L. Pal, A.K. and Jadhao, S.B. 2003. Effect of plant proteolytic enzyme on the physical-chemical properties and lipid profile of meat from culled, desi and broiler chicken. *Asian-Australasian Journal of Animal Science*, 16: 884-888.

- Thompson, E.H., Wolf, I.D. and Allen, C.E. 1973. Ginger rhizome: A new source of proteolytic enzyme. *Journal of Food Science*, 38: 652-655.
- Wardlaw, F.B., McCaskill, L.H. and Acton, J.C. 1973. Effect of post-mortem muscle changes on poultry meat loaf properties. *Journal of Food Science*, 38: 421-423.
- Witte, V.C., Krause, G. and Bailey, M.E. 1970. A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. *Journal of Food Science*, 35: 582-585.
- Zhao, G.Y., Zhou, M.Y., Zhao, H.L., Chen, X.L., Xie, B.B., Zhang, X.Y., He, H.L., Zhou, B.C., Zhang, Y.Z. 2012. Tenderization effect of cold-adapted collagenolytic protease MCP-01 on beef meat at low temperature and its mechanism. *Food Chemistry*, 134: 1738-1744.
- Zochowska-Kujawska, J. Lachowicz, K. Sobczak, M. Nedzarek, A. and Torz, A. 2013. Effects of natural plant tenderizers on proteolysis and texture of dry sausages produced with wild boar meat addition. *African Journal of Biotechnology*, 12: 5670-5677.