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ARTICLE

Effect of Cooking Condition on the Water-Soluble Flavor Precursors in Various Beef Muscles from Hanwoo (Korean Cattle)

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Abstract

This study was carried out to investigate the effect of cooking condition on the water-soluble flavor precursors relevant to *postmortem* glycogen metabolisms in various beef muscles from Hanwoo (Korean cattle). The loins, striploins, top rounds, and eye of rounds from 40-mon-old heifers were cooked in either with 100°C water bath (wet-cooking) or 180°C household electric oven (dry-cooking) until attained to about 80°C of internal temperature before the measurements of amounts of macroglycogen, proglycogen, free glucose, and lactate. The macroglycogen and proglycogen contents were not significant differences in all beef muscles between the wet-cooking and dry-cooking treatments. Regardless of cooking condition, the both loin and top round had higher ($p<0.05$) two types of glycogen than the eye of round. The free glucose and lactate contents presented higher trends in the dry-cooking treatment compared with the wet-cooking treatment. The wet-cooked top round had higher ($p<0.05$) free glucose than the wet-cooked eye of round. Moreover, the top round contained the highest lactate content regardless of cooking condition. Consequently, it is considered that the dry-cooking treatment would be more beneficial to the flavor of cooked beef muscles than the wet-cooking treatment.

Key words: cooking, flavor precursor, glucose, lactate, beef, Hanwoo

Introduction

The current trends of meat market have being turned from the quantitative consumption to the qualitative consumption in some of the advanced countries in the world because of economic growth and prevalence of well-being and LOHAS (Lifestyle of Health and Sustainability). Simply put, consumers, when buy the meat, consider the quality more important than the quantity. The majority of them, as well, want to purchase the high quality meat despite payment of high prices (Stezer *et al*., 2008). Eating quality is very closely associated with consumer preference and is mainly dictated by texture, flavor, and juiciness (Savell *et al*., 1987). Particularly, coupling of aroma with taste, the flavor is the second-most effective factor (Bryhni *et al*., 2002). In a study on palatability grading model in beef, Cho and co-workers (2008) suggested that flavor accounted for 29.8% of the rate of total consumer satisfaction when tenderness and juiciness accounted respectively for 51.2% and 19.0%.

Meat flavor is the chemical product occurred by harmonizing among five fundamental tastes, such as umami, bitterness, saltiness, sweetness, and sourness, and many different volatile compounds developed from endogenous flavor sources in meat, that is, flavor precursors, such as carbohydrates, amino acids, peptides, nucleic acids, and fatty acids (MacLord, 1986; Shahidi, 1998). Among the biochemical components generated by *postmortem* carbohydrate metabolisms, residual glycogen and glucose bring out the unique aroma by forming maillard reaction compounds with amino acids in cooked meat (Hornstein and Crowe, 1960; Pethick *et al*., 1995). Also, glucose and lactate contribute the distinct taste to meat (MacLeod, 1994; Mottram, 1991).

Although a variety of factors, including livestock breed, feed, meat quality grade, aging, processing, and cooking, affect the meat flavor (Adhikari *et al*., 2004; Belk *et al*., 1993; Calkins, 2002; Koutsidis *et al*., 2008a, 2008b; MacKenna *et al*., 2004; Miller *et al*., 1997; Streff *et al*., 2003), cooking treatment may be the most effective for the flavor of meat because people usually eat the cooked meat. Cooking treatment significantly alters the composition of flavor precursors in meat (Alfaia *et al*., 2010; Sasaki *et*

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al., 2007). Sasaki *et al*. (2007) found that wet-cooking (water bath-cooking) treatment decreased amounts of total amino acids with glutamic acid, inosine monophosphate, and oligopeptide in pork. Moreover, Alfaia *et al*. (2010) revealed that boiled, microwaved, or grilled beef contained lower polyunsaturated fatty acids/saturated fatty acids ratio than raw beef. However, up to the present, little information on effect of cooking on the compounds relevant to *postmortem* glycogen metabolisms has been reported.

Therefore, this study was carried out to investigate the effect of cooking condition on the water-soluble flavor precursors, such as glycogen, glucose, and lactate, in various beef muscles from Hanwoo (Korean cattle).

Materials and Methods

Reagents and chemicals

Trizma base, bromothymol blue sodium salt (BTB), phenolphthalein, glucose assay kit (GAHK20), hydrazine sulfate salt, β-nicotinamide adenine dinucleotide hydrate (β-NAD; N7004), L-lactic dehydrogenase (From bovine heart; L2625), perchloric acid (PCA) solution, and hydrochloric acid (HCl) solution were purchase from Sigma-Aldrich Co. LLC. (St. Louis, MO, USA). Deionized water was obtained from a Milli-Q Water Purification Equipment (Millipore SAS, Molsheim, Alsace, France).

Preparation of samples and experimental design

Five-heads of Hanwoo (Korean cattle) heifers were raised until 40-mon-old at the Hanwoo Experimental Station, National Institute of Animal Science, Republic of Korea, slaughtered, and chilled overnight at 1°C. The loin, striploin, top round, and eye of round were collected from their left carcasses (1 head: grade 1^{++}B, 1 head: 1^{+}B, 1 head: 1^{+}C, 1 head: 1C, and 1 head: 2C) 24 h *post-slaughter* and the subcutaneous fat and connective tissue were removed. Following pulverization with liquid nitrogen, the lean meat (100-200 g) from all beef parts were stored at -80°C before experiments. Duplicate about 18 g of meat powders were weighed into Φ25×95 mm glass vials (03-338J, Thermo Fisher Scientific Inc., Waltham, USA), divided by cooking conditions into two groups, and heated in either with 100°C water bath (Wet-cooking treatment; BS-21, Jeio Tech Co., Ltd., Korea) or 180°C household electric oven (Dry-cooking treatment; EON-C301S, Tongyang Magic Co., Korea) until attained to about 80°C of average internal temperature (305B Digital Thermometer, Tecpel Co., Ltd., Taiwan). Immediately after cooled in ice water, all samples were utilized in experimental measurements.

Macroglycogen and proglycogen contents measurement

Macroglycogen (MG) and proglycogen (PG) contents were performed according to the procedure established by Adamo and Graham (1998). With 0.8 mL of ice-cooled PCA (3 M, USA) using a spatula, 0.1 g of samples were gently mixed, placed on ice in a refrigerator (2°C) for 30 min, and then centrifuged for 20 min at 2°C, 3,000 rpm (Avanti J-E Centrifuge, Beckman Coulter, Inc., USA). For the measurement of MG content, the supernatants (100 μL) were boiled with 1 mL of 1 N HCl for 120 min, to break down the glycogen to glucose, combined with pH indicator (BTB-phenolphthalein), and then neutralized using 2 M trizma base. The PG content was determined in the sediments by the same process to MG content. Following filtration through 0.45 μm syringe filter, as described by Kunst *et al*. (1984), the final solutions were reacted with 1 mL of glucose assay reagent (1.5 mM β-NAD-1 mM ATP-1 U/mL hexokinase-1 U/mL glucose-6-phosphate dehydrogenase) for 30 min at 37°C and measured at 340 nm using an UV/Visible spectrophotometer (ProteomeLab DU-800, Beckman Coulter, Inc., USA). The results were calculated as μmol of glucose per g of meat with millimolar extinction coefficient (6.22 $mM^{-1}cm^{-1}$) of β-NADH.

Free glucose content measurement

Free glucose content was measured using a glucose assay kit with the hexokinase method described by Kunst *et al*. (1984). Samples were mixed with cold PCA on ice using an Ultra-Turrax (T25 Digital, Ika Werke GmbH & Co., Germany) for 30 s at 13,500 rpm. The homogenates were centrifuged for 20 min at 2°C, 3,000 rpm (J-20XP Centrifuge, Beckman Coulter, Inc., USA) before filtering through 0.45 μm syringe filter. After mixed with glucose assay reagent, the filtrates were incubated for 30 min at 37°C and spectrophotometrically analyzed at 340 nm. The results were expressed as μmol of glucose per g of meat.

Lactate content determination

Lactate content was determined with the process reported by Gutmann and Wahlefeld (1974). Briefly, following centrifugation for 20 min at 2°C, 11,600 rpm (SCR-20A Himac Centrifuge, Hitachi Koki Co., Ltd., Japan), PCA extracts of samples were filtered through 0.45 μm syringe filter and mixed with 3.6 mL of 0.2 M hydrazine buffer (pH 9.6) and 200 μL of 40 mM β-NAD, and 100 μL of

800 U/mL L-lactic dehydrogenase, and then incubated at 37°C. The absorbance recordings (340 nm) were expressed as mg of lactate per g of meat with millimolar extinction coefficient of β-NADH.

Statistical analysis

All data from experimental parameters were analyzed by Analysis of Variance (ANOVA) of SPSS (2011) program and indicated as means±standard deviation (SD). Duncan's multiple range tests were conducted to compare the significant differences among the means of treatments at $p<0.05$.

Results and Discussion

Macroglycogen and proglycogen contents

The glycogen in animal muscles is classified into two types, i.e., macroglycogen and proglycogen (Lomako *et al*., 1991, 1993). The macroglycogen (MW: 10,000 kDa) is found in muscles at a high proportion to protein (about 0.4%) and easily dissolves in acid solution. On the other hand, the proglycogen (MW: 400 kDa) exists in muscles at a low proportion to protein (about 10%) and hardly melts in acid solution. The effect of cooking condition on the macroglycogen content in loin, striploin, top round, and eye of round from Hanwoo (Korean cattle) was presented in Fig. 1. In all four meat parts, there were no significant ($p>0.05$) differences for macroglycogen content between the wet- and dry-cooking treatments. The wet- or dry-cooked loin, striploin, and top round significantly ($p<0.05$) contained higher macroglycogen content compared with the cooked eye of round. Regardless of meat parts, the proglycogen content (Fig. 2) was also not significantly different by cooking condition. Within the dry-cooking treatment, the both loin and striploin significantly ($p<0.05$) had higher proglycogen content than the eye of round. Thus, cooking condition did not influence on the macroglycogen and proglycogen contents in beef muscles from Hanwoo. Till the present, no data on effect of cooking condition on not only total glycogen but two types of glycogen have been reported. However, this result is similar with a previous finding of Ferguson *et al*. (2008), who observed that the both macroglycogen and proglycogen contents of *M. longissimus thoracis et lumborum* was higher than those of both *M. semimembranosus* and *M. semitendinosus* in lamb.

Free glucose content

The effect of cooking condition on the free glucose content in Hanwoo beef muscles was indicated in Fig. 3. No significant differences were found for free glucose content between the wet- and dry-cooking treatments, but the dry-cooking treatment showed the tendency including higher free glucose content compared with the wet-cook-

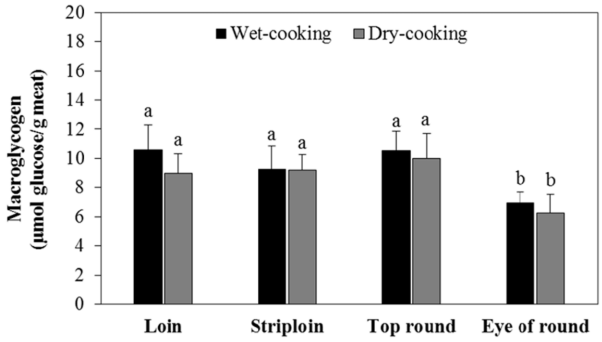

Fig. 1. Effect of cooking condition on the macroglycogen content in various muscles from Hanwoo (Korean cattle). Values are means±SD. [a-b]Different letters indicate significant differences among treatments ($p<0.05$).

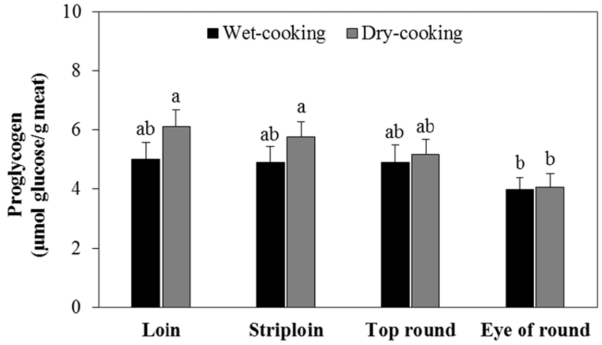

Fig. 2. Effect of cooking condition on the proglycogen content in various muscles from Hanwoo (Korean cattle). Values are means±SD. [a-b]Different letters indicate significant differences among treatments ($p<0.05$).

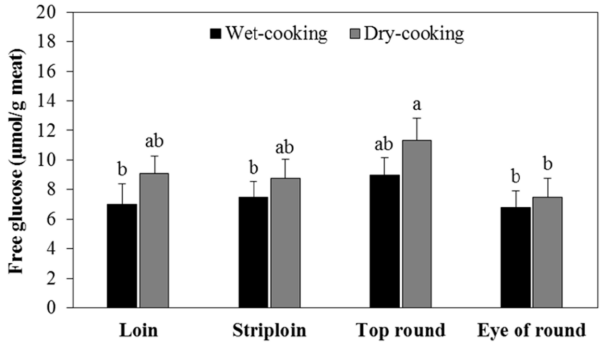

Fig. 3. Effect of cooking condition on the free glucose in various muscles from Hanwoo (Korean cattle). Values are means±SD. [a-b]Different letters indicate significant differences among treatments ($p<0.05$).

ing treatment. Within the wet-cooking treatment, the top round significantly (p<0.05) had higher free glucose content than the eye of round. Cooking treatment causes not only the water loss (cooking juice) but also the spill of water-soluble flavor precursors for meat (Chikuni *et al*., 2002). Besides, strong cooking condition leaks more cooking juice, which can lead to the loss of more water-soluble precursors (Sasaki *et al*., 2007; Vasanthi *et al*., 2007). Thus, in our study, the difference for glucose content by cooking condition would be probably the reason why the dry-cooking treatment resulted in lower cooking juice compared with the wet-cooking treatment. This finding is supported by a report of Mora and others (2011), who found that the low steam-cooking treatment showed lower cooking juice loss than the high steam-cooking treatment. In addition, Alfaia and others (2010) observed that grilling caused about 7.3% lower cooking loss than boiling, leading to about 6.9% and 14.3% higher true retention values [{(nutrient content per g of cooked meat × g of meat after cooking)/(nutrient content per g of raw meat × g of meat before cooking)} × 100] of moisture and total lipids in beef.

Lactate content

The lactate content (Fig. 4) also indicated higher trend in the dry-cooking treatment than in the wet-cooking treatment. In particular, significant (p<0.05) differences for lactate content were observed in the loin, striploin, and eye of round by cooking condition. In addition, the wet- or dry-cooked top round showed higher lactate content than the other muscles. In *postmortem* animal muscles, the lactate lowers pH value (Greaser, 1986), and serves the sour taste to cooked meat (Mottram, 1991). Because, unfortunately, in some of studies (Meiner *et al*., 2007, 2009), only effects of aging and genetics on the lactate content have been explained, it is not clear how cooking condition affects the lactate content. However, against findings of Chikuni *et al*. (2002), Mora *et al*. (2011), and Sasaki *et al*. (2007), we consider that the difference for lactate content may come from the difference for cooking loss between wet- and dry-cooking treatments.

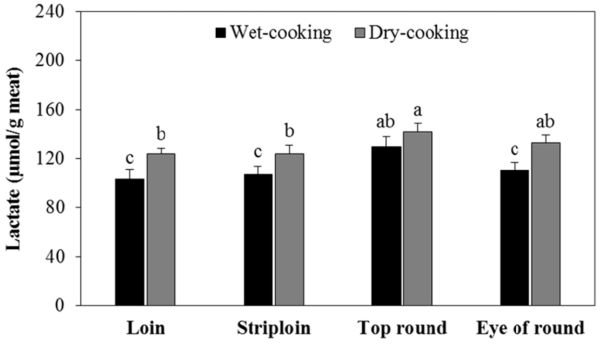

Fig. 4. Effect of cooking condition on the lactate content in various muscles from Hanwoo (Korean cattle). Values are means±SD. [a-c]Different letters indicate significant differences among treatments (p<0.05).

Conclusions

The effect of cooking condition (wet- and dry-cooking treatments) on the water-soluble flavor precursors related to *postmortem* carbohydrate metabolisms in loin, striploin, top round, and eye of round from Hanwoo (Korean cattle) was investigated in this study. Cooking condition influenced on the amount of glycogen-metabolized derivatives in Hanwoo beef muscles. Especially, the dry-cooking treatment maintained higher free glucose and lactate contents than the wet-cooking treatment. Although the measurement of cooking loss was not conducted in this study, it is regarded that these differences for contents of water-soluble precursors would originate in the difference for amount of cooking juice between two cooking conditions. So, further research is needed to be clear whether the dry-cooking treatment leads to lower cooking loss compared with the wet-cooking treatment.

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References

1. Adamo, K. B. and Graham, T. E. (1998) Comparison of traditional measurements with macroglycogen and proglycogen analysis of muscle glycogen. *J. Appl. Physiol.* **84,** 908-913.
2. Adhikari, K., Keene, M. P., Heymann, H., and Lorenzen, C. L. (2004) Optimizing beef chuck flavor and texture through cookery methods. *J. Food Sci.* **69,** 174-180.
3. Alfaia, C. M. M., Alves, S. P., Lopes, A. F., Fernandes, M. J. E., Costa, A. S. H., Fontes, C. M. G. A., Castro, M. L. F., Bessa, R. J. B., and Prates, J. A. M. (2010) Effect of cooking methods on fatty acids, conjugated isomers of linoleic acid and nutritional quality of beef intramuscular fat. *Meat Sci.* **84,** 769-777.
4. Belk, K. E., Miller, R. K., Evans, L. L., Liu, S. P., and Acuff, G. R. (1993) Flavor attributes and microbial levels of fresh beef roasts cooked in varying foodservice methodology. *J. Muscle Foods* **4,** 321-337.
5. Bryhni, E. A., Byrne, D. V., Rødbotten, M., Claudi-Magnus-

sen, C., Agerhem, H., Johansson, M., Lea, P., and Martens, M. (2002) Consumer perceptions of pork in Denmark, Norway and Sweden. *Food Qual. Prefer.* **13,** 257-266.
6. Calkins, C. R. (2002) Sensory differences among the beef value cuts. Proc. Am. Meat Sci. Assoc. Rec. Meat Con., Univ. of Missouri, Columbia, MO, USA.
7. Chikuni, K., Sasaki, K., Emori, T., Iwaki, F., Tani, F., Nakajima, I., Muroya, S., and Mitsumoto, M. (2002) Effect of cooking on the taste- and flavor-related compounds in pork. *Jpn. J. Swine Sci.* **39,** 191-199.
8. Cho, S. H., Kim, J. H., Kim, J. H., Seong, P. N., Park, B. Y., Kim, D. H., Lee, J. M., and Ahn, C. N. (2008) Prediction of palatability grading scores analyzed with sensory data of Hanwoo bull and steer beef. Proc. Ann. Cong. Korean Soc. Anim. Sci. Technol., Seoul National Univ., Seoul, Korea, pp. 136.
9. Ferguson, D. M., Daly, B. L., Gardner, G. E., and Tume, R. K. (2008) Effect of glycogen concentration and form on the response to electrical stimulation and rate of post-mortem glycolysis in ovine muscle. *Meat Sci.* **78,** 202-210.
10. Greaser, M. L. (1986) Conversion of muscle to meat. In: Muscle as food. Bechtel, P. J. (ed) Academic Press, Inc., Orlando, USA, pp. 37-102.
11. Gutmann, I. and Wahlefeld, A. W. (1974) L-(+)-lactate: Determination with lactate dehydrogenase and NAD. In: Methods of enzymatic analysis. Bergmeyer, H. U. (ed) Academic Press, Inc., NY, USA. Vol. 3, pp. 1464-1468.
12. Hornstein, I. and Crowe, P. F. (1960) Meat flavor chemistry: Flavour studies on beef and pork. *J. Agr. Food Chem.* **8,** 494-498.
13. Koutsidis, G., Elmore, J. S., Oruna-Concha, M. J., Campo, M. M., Wood, J. D., and Mottram, D. S. (2008a) Water-soluble precursors of beef flavour: I. Effect of diet and breed. *Meat Sci.* **79,** 124-130.
14. Koutsidis, G., Elmore, J. S., Oruna-Concha, M. J., Campo, M. M., Wood, J. D., and Mottram, D. S. (2008b) Water-soluble precursors of beef flavor: II. Effect of post-mortem conditioning. *Meat Sci.* **79,** 270-277.
15. Kunst, A., Draeger, B., and Ziegenhorn, J. (1984) Glucose: UV-methods with hexokinase and glucose-6-phosphate dehydrogenase. In: Methods of enzymatic analysis. Bergmeyer, H. U (ed) Academic Press, Inc., NY, USA. Vol. 6, pp. 163-172.
16. Lomako, J., Lomako, W. M., and Whelan, W. J. (1991) Proglycogen: A low-molecular-weight form of muscle glycogen. *FEBS Lett.* **279,** 223-228.
17. Lomako, J., Lomako, W. M., Whelan, W. J., Dombro, R. S., Neary, J. T., and Norenberg, M. D. (1993) Glycogen synthesis in the astrocyte: From glycogenin to proglycogen to glycogen. *FASEB J.* **7,** 1386-1393.
18. MacLeod, G. (1986) The scientific and technological basis of meat flavours. In: Developments in food flavours. Birch, G. G. and Lindley, M. G. (eds) Elesevier Applied Science, London, UK, pp. 191-223.
19. MacLeod, G. (1994) The flavour of beef. In: The flavor of meat and meat products. Shahidi, F. (ed) Blakie, Glasgow, USA, pp. 4-37.
20. McKenna, D. R., Lorenzen, C. L., Pollok, K. D., Morgan, W. W., Mies, W. L., Harris, J. J., Murphy, R., McAdams, M., Hale, D. S., and Savell, J. W. (2004) Interrelationships of breed type, USDA quality grade, cooking method, and degree of doneness on consumer evaluations of beef in Dallas and San Antonio, Texas, USA. *Meat Sci.* **66,** 399-406.
21. Meinert, L., Andersen, L. T., Bredie, W. L. P., Bjergegaard, C., and Aaslyng, M. D. (2007) Chemical and sensory characterization of pan-fried pork flavor: Interactions between raw meat quality, ageing and frying temperature. *Meat Sci.* **75,** 229-242.
22. Meinert, L., Tikk, K., Tikk, M., Brockhoff, P. B., Bredie, W. L. P., Bjergegaard, C., and Aaslyng, M. D. (2009) Flavour development in pork. Influence of flavor precursors concentrations in *longissimus dorsi* from pigs with different raw meat qualities. *Meat Sci.* **81,** 255-262.
23. Miller, M. F., Kerth, C. R., Wise, J. W., Lansdell, J. L., Stowell, J. E., and Ramsey, C. B. (1997) Slaughter plant location, USDA quality grade, external fat thickness and aging time effects on sensory characteristics of beef loin strip steak. *J. Anim. Sci.* **75,** 662-667.
24. Mora, B., Curti, E., Vittadini, E., and Barbanti, D. (2011) Effect of different air/steam convection cooking methods on turkey breast meat: Physical characterization, water status and sensory properties. *Meat Sci.* **88,** 489-497.
25. Mottram, D. (1991) Meat. In: Volatile compounds in foods and beverages. Maarse, H. (ed) Marcel Dekker, Inc., NY, USA, pp. 107-177.
26. Pethick, D. W., Rowe, J. B., and Tudor, G. (1995) Glycogen metabolism and meat quality. *Rec. Adv. Anim. Nutr. Aust.* **July,** 97-102.
27. Sasaki, K., Motoyama, M., and Mitsumoto, M. (2007) Changes in the amounts of water-soluble umami-related substances in porcine *longissimus* and *biceps femoris* muscles during moist heat cooking. *Meat Sci.* **77,** 167-172.
28. Savell, J. W., Branson, R. E., Cross, H. R., Stiffler, D. M., Wise, J. W., Griffin, D. B., and Smith, G. C. (1987) National consumer retail beef study: Palatability evaluations of beef loin steaks that differed in marbling. *J. Food Sci.* **52,** 517-519.
29. Shahidi, F. (1998) Flavor of muscle foods: An overview. In: Flavor of meat, meat products, and seafoods. Shahidi, F. (ed) Blackie Academic and Professional, London, UK, pp. 1-4.
30. SPSS. (2011) PASW Statistics 21. Statistical Package for the Social Sciences Incorporated, Illinois, USA.
31. Stezer, A. J., Cadwallader, K., Singh, T. K., Mckeith, F. K., and Brewer, M. S. (2008) Effect of enhancement and ageing on flavor and volatile compounds in various beef muscles. *Meat Sci.* **79,** 13-19.
32. Streff, B. A., Wulf, D. M., and Maddock, R. J. (2003) The effect of USDA quality grade, deep marination, and degree-of-doneness on palatability of gas grilled beef steaks from seven different muscles. Proc. Am. Meat Sci. Assoc. Rec. Meat Con., Univ. of Missouri, Columbia, MO, USA.
33. Vasanthi, C., Venkataramanujam, V., and Dushyanthan, K. (2007) Effect of cooking temperature and time on the physic-chemical, histological and sensory properties of female carabeef (buffalo) meat. *Meat Sci.* **76,** 274-280.

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