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Effects of market type and time of purchase on oxidative status and descriptive off-odors and off-flavors of beef in Vietnam

P.T.T. Vu[a], A.J. Holtcamp[b], A.T. Sukumaran[b], M.V.V. Le[a], D.H. Nguyen[a], T.T.N. Dinh[b,*]

[a] Department of Food Technology, Ho Chi Minh City University of Technology, Ho Chi Minh City, Viet Nam
[b] Department of Animal and Dairy Sciences, Mississippi State University, Mississippi State, MS, United States

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ABSTRACT

The objective of the current study was to determine the effects of market type (super market – SM, indoor market – IM, open market – OM) and sampling time (at the opening – T0 and 4 h after the opening – T4) on antioxidant capacity, lipid oxidation, and descriptive sensory attributes of beef in Vietnam. Values of FC and TEAC were greater in OM beef than IM and SM ($P < 0.001$) and FC value was also greater at T4 than T0 ($P = 0.038$). The beef from SM had 7% greater TBARS than IM and OM ($P = 0.003$). Livery odor was less intense in raw beef from OM when compared to SM and IM ($P \leq 0.047$). Sour odor in raw beef, and livery flavor in cooked beef was increased from T0 to T4 ($P \leq 0.035$). Principal component analysis of descriptive sensory attributes indicated that FC and TEAC could predict partial livery flavor in cooked beef, but not off-odors in raw beef.

1. Introduction

Beef quality is influenced by sensory and chemical attributes (Cardello, 1995; Molnar, 1995; Spanier, Vercellotti, & James Jr, 1992). Lipid oxidation is one the most important factors that affects the quality and shelf-life of raw and processed beef (Jo et al., 2006; Min & Ahn, 2005). Oxidation of lipids leads to the formation of various compounds such as aldehydes, which are responsible for off-odor, off-flavor, and rancidity (Ahn & Lee, 2002; Campo et al., 2006; Dietze, Lammers, & Ternes, 2007). Lipid oxidation in fresh meat is influenced by intrinsic factors such as degree of lipid saturation, concentration of antioxidants, heme pigments, and multi-valence metals such as iron (Du, Ahn, Nam, & Sell, 2000; Choe & Min, 2006; Calkins & Hodgen, 2007; Min, Nam, Cordray, & Ahn, 2008;), as well as extrinsic factors such as retail display time, temperature, light exposure, and type of packaging (Ahn, Nam, & Lee, 2009; Esmer, Irkin, Degirmencioglu, & Degirmencioglu, 2011; Kumar, Chatli, Wagh, Mehta, & Kumar, 2015). Inherent antioxidants such as vitamin E, glutathione peroxidases, superoxide dismutase, and tyrosine retard lipid oxidation in meat and preserve the sensory quality attributes and shelf-life (Roginsky & Lissi, 2005). Typical measurement of thiobarbituric acid reactive substances is well correlated with sensory attribute of meat (Campo et al., 2006; Dietze et al., 2007). However, antioxidant capacity may be better at predicting shelf life (Hayes, Stepanyan, Allen, O'Grady, & Kerry, 2010). Methods including ferric reducing antioxidant power (FRAP; Pulido, Bravo, & Saura-Calixto, 2000), trolox equivalent antioxidant capacity (TEAC; Re et al., 1999), and Folin-Ciocalteu (FC; Stratil, Klejdus, & Kubáň, 2006; Lee, Nomura, Patil, & Yoo, 2014) measure various antioxidant compounds and the ability of meat to scavenge free radicals.

Oxidation during retail display negatively influences sensory attributes of beef such as aroma, flavor, texture, and appearance (Calkins & Hodgen, 2007; Molnar, 1995; St. Angelo, Vercellotti, Jacks, & Legendre, 1996; Stelzleni & Johnson, 2008). Flavor and aroma are one of the most important sensory traits affecting consumers' purchase decision and acceptability of beef (Feuz, Umberger, Calkins, & Sitz, 2004; Robbins et al., 2003), especially in developing countries such as Vietnam. In Vietnam, beef markets vary in infrastructure and display conditions (McCain et al., 2015). Supermarkets usually have fresh beef displayed in refrigerated cases; whereas, in indoor and open markets, beef is displayed with direct exposure to sunlight and ambient temperature (McCain et al., 2015). Drastic differences in display conditions may have significant impacts on Vietnamese consumers' perception of freshness and acceptability of beef. Consumers in Vietnam tend to use aroma as indicator of beef freshness. However, differences in culinary experience in Vietnam from other developed countries present challenges in quantification of off-odors and off-flavor notes of fresh beef. The objective of the current study was to determine the effects of market type and sampling time on antioxidant capacity, lipid oxidation, and descriptive off-odors and off-flavors in beef across three regions of Vietnam.

* Corresponding author.
E-mail address: thu.dinh@msstate.edu (T.T.N. Dinh).

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2. Materials and methods

2.1. Sample collection

Sample collection ($N = 180$) occurred between January and May of 2015 and followed the similar procedure described by McCain et al. (2015). Briefly, Ho Chi Minh City, Da Nang, Ha Noi, and their surrounding areas were selected to represent the southern, central, and northern regions of Vietnam because there was variation in meat merchandising and climate among these regions. McCain et al. (2015) described the major differences in characteristics and infrastructure of supermarkets (SM), indoor markets (IM), and open markets (OM). Market type differentiated not only infrastructure but also marketing system, sources of products, methods of preservation, and display methods. Two of the most popular, geographically separated grocery markets per market type were selected in each region (locations available upon request). Only domestically produced beef were purchased in each market at two sampling times, the opening time (T0) and 4 h after opening (T4). The T0 was the opening of individual markets, which varied from 5 A.M. (OM and IM) to 8 A.M. (SM). The T4 was 4 h after the opening regardless when the opening was. Five 300-g beef *Longissimus* muscle samples were purchased separately, by different buyers, from various vendors in each market at each sampling time, resulting in 180 samples. This muscle was selected because it was present in the most valuable retail cuts in Vietnam meat markets. Not only were the beef vendors selected randomly, the order of sampling was also randomized. If a market had less than five vendors, at least one vendor was selected randomly to be sampled repeatedly in such a rotating order that samples from the same vendors were purchased at different times and from different beef strip loins to create as much variation as possible among samples. There was no vendor randomization in the SM because each SM was the sole meat vendor. However, beef samples from the SM were also purchased individually from different beef strip loins and by different purchasers. Similar randomization was performed at T4. The samples were transported separately in sterile Whirl-Pak® bags (Nasco, Fort Atkinson, WI) in an Igloo Super Tough Sportsman ice chest (Igloo, Katy, TX) with frozen ice packs after the meat surface temperature was recorded by a Fisher Scientific™ Traceable™ Infrared Thermometer Gun (Fisher Scientific, Waltham, MA). At a local university, in each region, samples were vacuum-packaged, frozen at −20 °C, transported to Ho Chi Minh City University of Technology on ice by airplane (1-h flight) to be stored at −20 °C until chemical and sensory analyses.

2.2. Antioxidant capacity analysis

2.2.1. Antioxidant extraction

A 0.5-g sample of *Longissimus* muscle was minced and placed into 15-mL polypropylene (PP) tubes, in which 2 mL of methanol was added, vortexed for 5 min, and centrifuged at 3000 ×*g* for 10 min at room temperature. A volume of 1.5 mL of supernatant was transferred into a 2-mL PP micro-centrifuge tube and centrifuged at 10000 ×*g* for 15 min at 4 °C. The extract was then used for antioxidant capacity analysis by three different methods.

2.2.2. Folin-Ciocalteu (FC) method

A volume of 150 μL of either antioxidant extract, trolox standard solutions (0.1, 0.2, 0.4, 0.6, and 0.8 mM), or methanol as blank was mixed with 75 μL of FC reagent. This mixture was vortexed for 10 s, kept at room temperature for 3 min, upon which 1125 μL of D-water and 150 μL of saturated Na_2CO_3 were added. This mixture was vortexed again for 10 s and centrifuged at 10000 ×*g* for 5 min at 25 °C. The absorbance was recorded at 765 nm, using a spectrophotometer (Lambda 35, Perkin Elmer, Waltham, MA). The FC value was expressed as millimoles of trolox equivalence per kg of sample (mmol/kg).

2.2.3. Ferric reducing antioxidant power (FRAP) method

The FRAP was determined using a method described by Benzie and Strain (1996). FRAP reagent was prepared by mixing 125 mL of 100-mM acetate buffer, 12.5 mL of 10-mM 2,4,6-Tris(2-pyridyl)-s-triazine in 40-mM HCl, and 12.5 mL of 20-mM $FeCl_3$ in water. A volume of 45 μL of either extract, trolox standard solutions, or methanol as blank was mixed with 300 μL of FRAP reagent and 1155 μL D-water, vortexed, kept at room temperature for 10 min, and centrifuged at 10000 ×*g* for 10 min at 25 °C. Absorbance was measured at 593 nm and the FRAP value was expressed as millimoles of trolox equivalence per kg of sample (mmol/kg).

2.2.4. Trolox equivalent antioxidant capacity (TEAC) method

This method determined total antioxidant capacity through discoloration of 2,2 –Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) radical cation ($ABTS^+$; Re et al., 1999), indicating the scavenging activity of the meat extract. The 7 mM 2,2′ –Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) and 2.45 mM potassium persulfate were mixed to form a solution of free radicals. The $ABTS^+$ solution was wrapped with foil aluminum and incubated for 6 h at room temperature until there was a stable concentration of $ABTS^+$, indicative by a constant, characteristic absorbance at 734 nm. The $ABTS^+$ stock solution was then diluted with water to achieve an absorbance of 0.85 at 734 nm. In a volume of 1400 μL of diluted $ABTS^+$ (0.85 absorbance), 70 μL of either meat extract, trolox standard solutions, methanol as sample blank, or water as reagent blank was added and the stable absorbance were recorded at 5 min after mixing at 734 nm using Lambda 35 UV/Vis spectrophotometer (Perkin Elmer, Inc., Waltham, MA). All absorbance was subtracted from the absorbance of reagent blank. Absorbance of samples and standard solutions was then subtracted from the absorbance of sample blank (methanol). The resulted absorbance was linearly correlated with the concentration of free radical scavengers in either meat extracts or trolox solutions. The TEAC value was expressed as millimoles of trolox equivalence per kg of sample (mmol/kg).

2.3. Thiobarbituric acid reactive substances (TBARS) method

Lipid oxidation was determined by TBARS as described by Draper et al. (1993). A 0.5-g muscle sample was minced and placed into a 15-mL polypropylene (PP) tube with 2 mL of 10% (*w/v*) trichloroacetic acid (TCA) containing 50 ppm butylated hydroxytoluene (BHT). The tube was incubated in 90 °C water bath for 30 min to extract malondialdehyde (MDA), cooled in ice, and centrifuged at 3000 ×*g* and 4 °C for 10 min. In a separate 15-mL PP tube, 1 mL of either the extract, MDA standard solution (2.5 to 25 mM), or extracting solution (10% TCA and 50 ppm BHT) as blank was mixed with 1 mL of saturated TBA solution and incubated in a 90 °C water bath for 30 min before being cooled in ice. At room temperature, the pigment was extracted in 1 mL of n-butanol by vortexing for 10 s, and centrifugation at 10000 ×*g* and 4 °C for 10 min. Supernatant was pipetted into micro-cuvette and absorbance was read at 532 nm using a Lambda 35 UV/Vis spectrophotometer (Perkin Elmer, Inc., Waltham, MA). The absorbance was compared against an external standard calibration curve of MDA and the TBARS value was reported as milligram of MDA per kg of meat (mg MDA/kg).

2.4. Descriptive off-odor and off-flavor analysis

2.4.1. Sample preparation

The samples were removed from the freezer 24 h prior to cooking and thawed at 4 °C. Samples for both training and the final experiment were prepared in the same procedure. Each sample was cut into a 50-g portion for fresh off-odor evaluation and a 250-g portion for cooked off-flavor evaluation. The 50-g portion was minced and 5 g of ground meat was placed in a 118-mL amber glass jar washed with distilled water and