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Consumer palatability scores and volatile beef flavor compounds of five USDA quality grades and four muscles

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ABSTRACT

Proximate data, consumer palatability scores and volatile compounds were investigated for four beef muscles (*Longissimus lumborum*, *Psoas major*, *Semimembranosus* and *Gluteus medius*) and five USDA quality grades (Prime, Upper 2/3 Choice, Low Choice, Select, and Standard). Quality grade did not directly affect consumer scores or volatiles but interactions ($P<0.05$) between muscle and grade were determined. Consumer scores and volatiles differed ($P<0.05$) between muscles. Consumers scored *Psoas major* highest for tenderness, juiciness, flavor liking and overall liking, followed by *Longissimus lumborum*, *Gluteus medius*, and *Semimembranosus* ($P<0.05$). Principal component analysis revealed clustering of compound classes, formed by related mechanisms. Volatile *n*-aldehydes were inversely related to percent fat. Increases in lipid oxidation compounds were associated with *Gluteus medius* and *Semimembranosus*, while greater quantities of sulfur-containing compounds were associated with *Psoas major*. Relationships between palatability scores and volatile compound classes suggest that differences in the pattern of volatile compounds may play a valuable role in explaining consumer liking.
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1. Introduction

Beef palatability is often believed to be most dependent on tenderness (Miller, Carr, Ramsey, Crockett, & Hoover, 2001; Miller et al., 1995; Savell et al., 1987). However, flavor is also considered a primary palatability factor and is shown to be of great importance when tenderness is acceptable (Behrends et al., 2005a, 2005b; Goodson et al., 2002; Killinger, Calkins, Umberger, Feuz, & Eskridge, 2004). Flavor has been identified as the single most important factor in determining consumer acceptability when meat was prepared at home (Huffman et al., 1996). Beef flavor is a combination of taste and odor. While taste is generally detected on the tongue as sweet, sour, salty, bitter or other taste sensations such as "umami", odor or aroma is detected in the nose and plays a large role in flavor perception. Numerous volatile compounds have been identified from beef, including: sulfur-containing compounds, furanthiols, disulfides, aldehydes, ketones and other heterocyclic compounds (Cerny & Grosch, 1992; Farmer & Patterson, 1991; Gasser & Grosch, 1988; Mottram, 1991).

Consumers have associated increased flavor desirability with increased intramuscular fat (O'Quinn et al., 2012; Smith, Savell, Cross, & Carpenter, 1983). However, laboratory studies have repeatedly found that increased intramuscular fat rarely produces increases in volatile flavor compounds (Cross, Berry, & Wells, 1980; Mottram & Edwards, 1983; Mottram, Edwards, & Macfie, 1982). Evidence from studies on meat products suggests that fat acts as a solvent for volatile compounds, thus delaying flavor release (Chevance et al., 2000). Documentation of the effect of USDA quality grade among multiple beef muscles upon volatile flavor compounds was not found in the literature.

Research regarding differences in flavor among muscles has focused on flavor intensity and the presence of off-flavors. Calkins and Hodgen (2007) have summarized muscle rankings based on flavor intensity and off-flavors. In most cases flavor intensity and off-flavors were correlated with each other. Volatile compounds associated with lipid oxidation have been reported to vary between muscles of the chuck and round influencing perceived flavor (Hodgen, Cuppett, & Calkins, 2006). Recently a beef flavor lexicon of beef attributes was used to determine differences between top loin, top sirloin, tenderloin, and inside round steaks (Adhikari & Chambers, 2010; Miller, 2010).

To date, no studies have assessed the palatability and volatile profile of multiple beef muscles in various quality grades. The objective of this study was to determine the effects of USDA quality grade and

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muscle on consumer palatability perception and volatile beef flavor compounds.

2. Materials and methods

2.1. Product procurement and preparation

Boneless striploins [Institutional Meat Purchase Specifications (IMPS) 180, North American Meat Processers Association (NAMP, 2010)], tenderloins (IMPS 189, NAMP), inside rounds (IMPS 169, NAMP), and top sirloins (IMPS 184, NAMP) were collected from three 'A' maturity (9 to 30 month animals at harvest) carcasses representing each of five USDA quality grades (Prime, Upper 2/3 Choice, Low Choice, Select, and Standard) at a commercial beef processing facility in the Midwest region of the United States. Carcasses were selected by trained individuals who assessed the amount of visual intramuscular fat of the ribeye face at the 12th and 13th rib along with lean color and skeletal ossification (USDA, 1997). Subprimals of the selected carcasses were vacuum packaged and transported to the Gordon W. Davis Meat Laboratory where they were stored at 2 to 4 °C in the absence of light, and aged to 21 days postmortem prior to fabrication. Steak cutting, selection and cooking followed Meat Standards Australia (MSA) protocols (Watson, Gee, Polkinghorne, & Porter, 2008). The muscles, *Longissimus lumborum*, *Psoas major*, *Semimembranosus*, *and Gluteus medius* (from striploin, tenderloin, inside round, and top sirloin subprimals, respectively) were denuded of all epimysium and fat. *Semimembranosus and Gluteus medius* muscles were sectioned parallel with muscle fibers in order to allow steak cutting across the grain. *Longissimus lumborum* and *Psoas major* muscles were cut perpendicular to the length of each muscle having some grain angle, specifically in *Longissimus lumborum* steaks. All muscles were cut into 25 mm thick steaks approximately 10 cm × 5 cm in length and width, starting at the anterior end of the muscle or muscle section. The resulting steaks were individually wrapped in plastic, vacuum packed in sets of five, identified with a unique sample code and frozen (−20 °C). Frozen wrapped steaks were later sorted into predetermined groups of 10 steaks, each being a single steak from 10 of the original sample codes, representing a cooking round and re-vacuum packaged. This re-sorting was determined by MSA protocols and related software routines to produce a six by six latin square presentational order in which six test products were arranged so that each product was cooked and served an equal number of times in each of six presentational orders (serving rounds two to seven) and served before and after each other product an equal number of times. The first cooking and serving round utilized a common presumed mid position "starter" served to all consumers. The five individual steaks from each original sample were placed and served in five different rounds to counter potential order effects.

2.2. Consumer palatability scores

Consumer palatability scoring was conducted in accordance with MSA protocols (Watson et al., 2008). Steaks were thawed at 2 to 5 °C for 24 h prior to cooking. All steaks were cooked using a Silex clamshell grill (model S-143 k, Silex Grills Australia Pty. Ltd., Marrickville, Australia). Plate surface temperature was set at 225 °C and preheated 45 min prior to panels. Each panel session was conducted using a count up timer and timed schedule. Each session commenced with cooking of a warm up load to stabilize grill recovery temperatures prior to the seven cooking rounds. Loading and unloading of both the warm up and subsequent six test rounds was conducted in accordance with the time schedule as was serving of test samples. During panels steaks were loaded on the grill in seven designated groups (rounds) of 10. The grill surface was scraped, cleaned and greased with non-flavored cooking spray (Pam® Original Non-Stick Cooking Spray, ConAgra Foods, Inc., Omaha, NE, USA) between rounds. Steaks were cooked 5 min with the grill closed, removed at the designated time and allowed to rest for 3 min. During resting three 1.27 cm diameter cores were removed across the center line of selected steaks for volatile analysis by coring through the thickness of steaks perpendicular to cut surfaces in order to produce cores of similar volume (approximately 2.5 cm in length and 1.27 cm in diameter). After the resting period each steak was cut into two pieces (across the cored section), and immediately served to two designated consumers.

Sessions were conducted in evenings by paid consumers (n = 278) recruited from Lubbock, TX, USA and the surrounding area. Consumers were recruited from various community and charity groups with the group paid for attendance as a fund raiser rather than paying individuals. Consumers were screened to include only regular beef eaters that preferred "medium doneness."

Each consumer was assigned to a numbered booth containing a ballot, plastic knife, plastic fork, toothpicks, napkins, a cup of water, an expectorant cup, and between sample palate cleansers (a 10% apple juice, 90% water solution and unsalted crackers). Panelists were verbally instructed to utilize the provided plastic utensils to cut steaks into bite sizes similar to their normal beef consumption habits.

Groups of 20 consumers each evaluated seven steaks, the first a standard "starter", chosen to be of a mid-range quality, to acclimate consumers, followed by one from each of six product groups encompassing a wide quality range derived from multiple muscles and USDA quality grade. Each steak was rated on a 100-mm continuous line scale for tenderness, juiciness, flavor liking and overall liking. On the scale, zero was verbally anchored as "not tender," "not juicy," "dislike flavor extremely," and "dislike overall extremely." Conversely, 100 was verbally anchored as "very tender", "very juicy", "like flavor extremely", and "like overall extremely". The MSA "MQ4" score was calculated as a weighted consumer score between one and 100, using the standard MSA weightings of 30% for tenderness, flavor and overall liking and 10% for juiciness.

2.3. Volatile compound evaluation

Volatile compound collection and gas chromatography–mass spectrometry (GC–MS) analysis was conducted on selected steaks from those that were grilled and served to consumers during each evening's consumer panel. Samples for volatile collection were collected from the selected steaks, once removed from the grill, by obtaining three 1.27-cm diameter cores from the center line of selected steaks during the resting period and before the remaining steak was cut into two portions and served to two consumers. Each core was then cut again perpendicular to the muscle fibers to enable the six pieces to be placed into a 15 mL clear glass vial (Supelco, Bellefonte, PA, USA; preconditioned in an oven held at 95 °C). Preheated (60 °C) vials and screw caps containing a polytetrafluoroethylene septum were then closed. The vial was then placed in a 65 °C water bath (Thermo Scientific, Waltham, MA, USA) and allowed to equilibrate for 5 min. Volatiles were extracted by solid phase microextraction (SPME) using an 85 μm film thickness carboxen polydimethylsiloxane fiber in a manual SPME needle and holder (Supelco, Bellefonte, PA, USA). Following equilibration, a SPME fiber was placed in the headspace above the sample for 10 min. After collection, samples were withdrawn into the SPME needle, capped using an inert GC septum (LB-2, Supelco, Bellefonte, PA, USA) and placed in a glass test tube with a PTFE-lined lid (all preheated in an oven at 95 °C). The SPME fibers with collected volatiles were held at 2 to 4 °C for up to a maximum of 24 h, prior to analysis. Collection and holding was required as multiple volatile samples were collected simultaneously during consumer palatability scoring sessions.

An Agilent 6890 series GC (Agilent Technologies, Santa Clara, CA, USA) equipped with a 5975 MS detector (Agilent Technologies, Santa Clara, CA, USA) was used for separation and detection of volatile compounds. Extracted volatile compounds were desorbed from SPME fibers at the GC–MS inlet at 250 °C in splitless mode. Cryogenic focusing was conducted by placing the front of the GC column into a bed of dry ice (solid CO_2). A loop of the front end of the column (approximately

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