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Determination of volatile aroma compounds in beef using differences in steak thickness and cook surface temperature

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ABSTRACT

Top loin steaks with a United States Department of Agriculture (USDA) grade of Select were cut 1.3 cm, 2.5 cm, or 3.8 cm thick and cooked on a skillet at 177 °C, 204 °C, or 232 °C. Aroma compounds described as fatty, tallow, and oily are highly related to the identity of beef flavor. These compounds are produced in the highest quantity when steaks are cooked either at low temperatures (177 °C) or for short periods of time. Whereas, aroma compounds described as roasted, nutty, or fruity are developed from browning the surface of the steak as a result of cooking at high skillet surface temperatures (232 °C) or for long periods of time, as would be seen cooking thick steaks (3.8 cm). This study shows that the amount of specific aroma compounds can be predicted (r^2 values up to 0.62) from measured cooking times and temperatures. It may be possible to develop beef steak flavor by recommending steak thickness and cooking temperatures.

1. Introduction

Beef flavor is an incredibly complex and not completely understood quality trait. While Calkins and Hodgen (2007); Kerth and Miller (2015); and Mottram (1998) have done an admirable job of reviewing current literature and describing many of the factors involved in determining beef flavor, much still needs to be done. Basic flavor components are generally classified into two categories: lipid-derived and Maillard Reaction Products (MRP; Mottram, 1998). During cooking, lipids are degraded giving various derivative compounds that are aromatic; on the other hand, MRP are results of the combination of heat, sugar, and amino acids. The meat supplies the sugar (primarily ribose) and amino acids from the high protein content. Thus, meat heated to over 120 °C at the surface results in browning and the production of hundreds of aromatic compounds with very low aroma thresholds (parts per quadrillion in some cases; Mottram, 1998).

While research has shown that cooking method influences flavor development (Berry & Leddy, 1990; Lorenzen et al., 1999), the method of cookery is most times confounded with cooking temperature (as shown in Berry & Leddy, 1990). Although Brooks et al. (2000) and Guelker et al. (2013) reported the consist of steak thickness found at retail and reported no effects on tenderness, no research can be found that determines the impact of steak thickness on flavor or palatability. We hypothesize that as the steak thickness increases, and the meat is in contact with the cooking surface for a longer period of time, more MRP would be formed. We also hypothesize that higher cooking surface temperatures will produce more MRP. The objectives of this project were to determine the ability to generate and document aromatic chemical compounds generated by steaks cut 1.3 cm, 2.5 cm, or 3.8 cm thick cooked to a medium degree of doneness at a low (177 °C), medium (204 °C), or high (232 °C) cook surface temperature.

2. Materials and methods

2.1. Steak preparation and cooking

Strip loins that graded United States Department of Agriculture (USDA) Select were ordered from a commercial distributor and originated from a major packing plant. The strip loins were placed in the freezer after aging 14 d post-processing to allow uniform and precise cutting thickness of the steaks on a band saw. After intact strip loins were frozen (−10 °C), each loin was divided into nine portions 1.3 cm, 2.5 cm, or 3.8 cm thick completely at random and each of these steak thicknesses were assigned a cooking treatment to be cooked on a flat skillet with a surface temperature of 177 °C, 204 °C, or 232 °C (a 3 cooking temps × 3 steak thicknesses factorial arrangement; nine steaks per strip loin). The frozen steaks were labeled and vacuum-packaged individually and placed into frozen storage (−10 °C) until analyses. Individual steaks for cooking were selected and thawed in refrigerated (4 °C) storage for 12 to 24 h.

For cooking, 30.4-cm-diameter cast iron skillets were placed on gas range burners and heated to the desired surface cooking temperature (177 °C, 204 °C, or 232 °C; General Model IRT207 Infrared Thermometer,

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Secucus, NJ, USA) and allowed to remain at the selected temperature for at least 15 min before each steak was placed in the pan. Prior to cooking, the cooking surface of the cast iron skillet, the surface temperature of the steak, and the internal temperature of the steak were recorded. Steaks for all cooked analyses were weighed raw, then placed on the grill, and turned when the internal temperature reached 35 °C. Side 1 cooking time, side 1 skillet temperature, and side 1 steak cooked surface temperature were recorded. Finally, steaks were removed when the internal temperature reached 71 °C and side 2 cooking time, side 2 skillet temperature, side 2 steak cooked surface temperature, and total cooking time were recorded. Internal temperatures were monitored by iron–constantan thermocouples (Omega Engineering, Stanford, CT) inserted into the steak or roast geometric center. Temperatures were displayed using an Omega HH501BT Type T thermometer. After removal, each steak was weighed to determine the percentage cooking loss (((raw weight − cooked weight) / (raw weight)) × 100).

2.2. Gas chromatography/mass spectroscopy

After steaks were cooked, all external fat was removed, and each steak was cut into pieces as would be done for sensory (1.3 cm × 1.3 cm × steak thickness cubes), 12 pieces were placed in a 473 mL glass jar with a Teflon lid, and placed in a water bath held at 60 °C to approximate normal holding temperature for sensory analyses. After equilibrating for 20 min, a solid-phase micro-extraction (SPME) Portable Field Sampler (Supelco 504831, 75 μm Carboxen/polydimethylsiloxane [PDMS], Sigma-Aldrich, St. Louis, MO) was inserted through the lid and the headspace above each meat sample in the glass jar was collected for 2 h. Upon completion of collection, the SPME was removed from the jar and injected into the injection port of a gas chromatograph (GC; Agilent Technologies 7920 series GC, Santa Clara, CA), where the sample was desorbed at 280 °C for 3 min. The sample was then loaded onto the multi-dimensional gas chromatograph into the first column (30 m × 0.53 mm ID/BPX5 [5% phenyl polysilphenylene-siloxane] × 0.5 μm, SGE Analytical Sciences, Austin, TX). Through the first column, the temperature started at 40 °C and increased at a rate of 7 °C/min until reaching 260 °C. Upon passing through the first column, the compounds passed on to a second column (30 m × 0.53 mm ID [BP20 — polyethylene glycol] × 0.50 μm, SGE Analytical Sciences). The GC column then went to a mass spectrometer (MS; Agilent Technologies 5975 series MS, Santa Clara, CA) for quantification and identification using the Wiley Chemical Library.

2.3. Statistical analyses

Data for cooking times, cooking temperatures, cooking losses, and chemical compounds were analyzed as a 3 (177, 204, or 232 °C cooking surface temperature) × 3 (1.3-, 2.5-, or 3.8-cm-thick steaks) factorial arrangement of a randomized block (cooking day) design. When significant ($P < 0.05$) F-tests were found, means were separated using Fisher's protected least significant differences (LSD; a pair-wise t-test) with alpha set at 5%. Chemical compounds identified to be significant contributors to beef flavor (Berry & Leddy, 1990; Calkins & Hodgen, 2007; Kerth & Miller, 2015; Maruri & Larick, 1992; Moon, Cliff, & Li-Chan, 2006; Shahidi, Rubin, D'Souza, Teranishi, & Buttery, 1986) were used to develop stepwise regression equations with the chemical compound serving as the dependent variable and the cooking times, temperatures, and cooking loss used as independent variables in stepwise regression analysis. In the forward stepwise, *P*-values of 0.25 and 0.25 were used for entry and exit from the model, respectively. All statistics were analyzed using JMP (SAS Institute, Inc., Cary, NC).

3. Results

3.1. Cooking surface and steak temperatures

Cooking surface temperature effects on the steak and cooking temperatures are shown in Fig. 1. Naturally, the cooking surface temperature did not impact the beginning steak surface, beginning internal, or ending internal temperatures. As the cooking surface temperature treatment levels increased, the beginning, flipped, and ending skillet temperatures also increased ($P < 0.05$). Interestingly, in all three cooking temperature treatments, the surface temperature of the skillet decreased by about 50 °C at the point that the steak was turned, and another 25 to 50 °C by the time that the steak was removed from the skillet. It is well understood that putting a cool steak on the cooking surface will reduce the cooking surface temperature, but additionally, the moisture migration out of the steak also cools the cooking surface. This may be reflected in the fact that the surface temperature of the steak never got above the boiling point (100 °C). Accordingly, additional research is needed in mapping the temperature of the steak as most literature indicates that the formation of MRP begins at 120–150 °C. It is possible that the momentary temperature of the surface was in fact much higher (as indicated by the temperature of the skillet), but that the temperature of the steak surface was below 100 °C when momentarily removed for measurement.

Steak thickness did not affect ($P > 0.05$, Fig. 2) beginning steak surface, beginning skillet, flipped steak surface, ending steak surface, or ending steak internal temperatures. The beginning steak internal temperatures were higher for 1.3 and 2.5 cm steaks compared to 3.8 cm steaks mainly due to the slight warming of the steaks held briefly at room temperature prior to cooking. The thinner steaks warmed more quickly than the thicker steaks. The temperature of the skillet at the point of turning as well as the end of cooking was higher ($P < 0.05$)

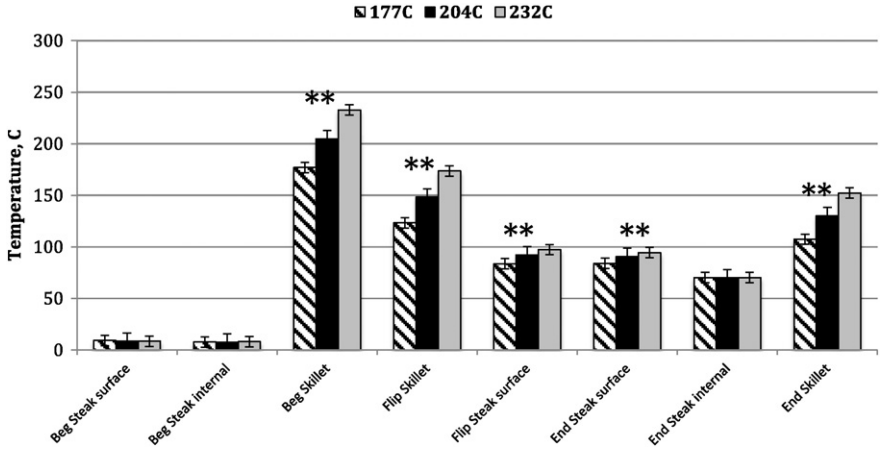

Fig. 1. Cooking surface temperature effects on steak and skillet temperatures. **Means within a group are significantly different ($P < 0.05$).