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Time and Temperature Kinetics for the Development of Volatile and Non-Volatile Flavor Compounds in Steaks

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Objectives

The objective of this study was to utilize mass spectrometry (MS) instrumentation to define flavor differences in beef strip loin steaks cooked on five different surface temperatures.

Materials and Methods

USDA Select strip loins ($n = 30$) were selected from carcasses at a commercial major packing plant in Texas. After aging 14d, the loins were cut into 2.54 cm thick steaks, randomly assigned a grill surface temperature of 149, 177, 204, 232, or 260°C, individually vacuum-packaged and frozen at –10°C until analysis. Steaks were cooked on an electric flat top grill pre-heated to the corresponding temperature treatment. Steaks were turned at an internal temperature of 35°C and removed at 71°C (medium degree of doneness). Cubes (1.3cm × 1.3cm × steak thickness) representative of those served to a trained sensory panel were frozen and held at –80°C until further analysis. For GC/MS analysis, the samples were weighed and placed in a 473 mL glass jar with a Teflon lid held in a water bath at 60°C for 2h. The collection of volatiles from the headspace was done with a solid phase micro-extraction (SPME) sampler and a multi-dimensional GC/MS. For HPLC/MS-QTOF analysis, frozen samples were homogenized in a blender and 2 g were mixed with 8 mL acidified acetonitrile (0.1% formic acid). The supernatant was exposed to dSPE Enhanced Matrix Removal and dried with 3.5 g $MgSO_4$. Samples were analyzed at a 1:5 dilution using reverse-phase chromatography on an Agilent 6545 LC/MS-QTOF with a gradient mobile phase in both positive and negative ion modes. Data were analyzed as linear and/or quadratic effects ($P < 0.05$) with grill surface temperature as the independent variable. Least squares means, discriminant analyses, and partial least squares regression analyses for compounds were calculated.

Results

Both octane (gasoline aroma) and undecane (allspice aroma) increased ($P < 0.02$) linearly with grill temperature. With the exception of pentanal (fermented wine aroma), which decreased ($P = 0.027$) as grill temperature increased, all other aldehyde compounds increased ($P < 0.05$) linearly as the grill temperature increased. Pyrazines (roasted, coffee, and nutty aromas) and ketones (fruity, fatty aromas) generally increased ($P < 0.03$) as grill temperature increased. 2,3,5-trimethyl-6-ethyl pyrazine, 2,3-diethyl-5-methyl pyrazine, 2,5-dimethyl pyrazine and 3,5,-diethyl-2-methyl-pyrazine were only present when the grill temperature reached 260°C. Nonvolatile compounds ($n = 247$ positive ion and 140 negative ions) were identified. Significant ($P < 0.05$) patterns of increasing intensity with increased grill temperature were observed in sugar-amino derivatives such as betaine, 2-dimethylamino-5,6-dimethylpyrimidin-4-ol, and (S)-N-(4,5-dihydro-1-methyl-4-oxo-1H-imidazol-2-yl) alanine. A point of inflection was observed at a grill temperature of 232°C across a majority of increasing compounds, suggesting a critical temperature for the regulation of flavorful products from the Maillard reaction.

Conclusion

Volatile and nonvolatile compounds known to contribute to positive flavor attributes associated with the Maillard reaction are considerably influenced by grill surface temperature. It appears that a grill temperature from 204 to 232°C is optimal for generation of volatile and nonvolatile flavor compounds.