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Relationships between sensory descriptors, consumer acceptability and volatile flavor compounds of American dry-cured ham

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ABSTRACT

The relationships between volatile flavor compounds, sensory descriptors and consumer acceptability were determined for eight commercial American dry-cured hams using external preference and flavor mapping. The majority of consumers preferred ($p < 0.05$) hams that had more intense caramelized, smoky, savory and molasses aromas as well as more intense sweet and savory flavors. Sixteen aroma impact compounds were identified from the headspace volatiles of dry-cured hams. The majority of consumers preferred ($p < 0.05$) hams that were characterized by 4-methyl-2-methoxyphenol (sweet ham), 4-ethyl-2-methoxyphenol (sweet ham), 2-methoxyphenol (smoky, cocoa), 2,6-dimethoxyphenol (smoky ham, savory) and 2-furanmethanol (burnt meat, vitamin). Fourteen percent of consumers preferred ($p < 0.05$) two hams that were characterized by methional (baked potato). Consumer acceptability scores were lower for hams either characterized by methanethiol (sulfur), carbon disulfide (sulfur), 2-butanone (sweet), 3-methylbutanal (malty, fermented), 2-heptanone (burnt meat, vitamin), hexanal (cut grass), benzeneacetaldehyde (floral), 1-octen-3-ol (mushroom) or characterized by benzaldehyde (burnt meat, cooked meat) and limonene (citrus). This study revealed how relationships between sensory descriptors, consumer acceptability and volatile flavor compounds could be determined using external preference mapping and used to comprehend the nature of dry-cured ham flavor as it is perceived by a consumer panel.

1. Introduction

Country style or country-cured ham refers to American dry-cured ham, a value-added product characterized by unique and aged flavors. This product is a valued tradition in the Southern United States with regional variations in its curing, smoking and aging stages that result in subtle differences in the final flavor of the meat product (Marriott & Ockerman, 2004). It is during the aging period that the hams are subjected to various combinations of time, temperature, and humidity treatments, which can last from 90 to 360 days, depending on the final quality and desired product flavor. Sufficient aging of the product is necessary for the development of characteristic flavors that enhance consumer appeal (Marriott & Ockerman, 2004).

Flavor and aroma are key attributes that impact the overall acceptance of dry-cured hams and are markedly affected by raw material, processing techniques, and aging time (Dirinck, Van Opstaele, & Vandendriessche, 1997; Ockerman, Blumer, & Craig, 1964; Sánchez-Peña, Luna, Garcia-Gonzalez, & Aparicio, 2005). The flavor and aroma of dry-cured ham can be determined by sensory descriptive analysis and the composition of aroma impact compounds, most of which are produced post-mortem by chemical and enzymatic mechanisms (Flores, Grimm, Toldrá, & Spanier, 1997a). Several studies have been conducted to identify and quantify the volatile compounds in different types of dry-cured hams including Iberian (Carrapiso, Ventanas, & García, 2002; Ruiz, Ventanas, & Cava, 2001), Serrano (Flores et al., 1997a; Flores, Spanier, & Toldrá, 1998), Parma (Barbieri et al., 1992; Careri et al., 1993), Black Forest (Wittkowski, Ruther, Drinda, & Rafiei-Taghanaki, 1992), Jinhua (Zhang, Wang, Liu, Zhu, & Zhou, 2006) and French hams (Buscailhon et al., 1994). Compared to the aforementioned dry-cured ham products, no recent studies (Lillard & Ayres, 1969; Ockerman et al., 1964; Piotrowski, Zaika, & Wasserman, 1970) have been published on the volatile profile and sensory quality of American dry-cured hams. A study on the volatile composition of American dry-cured ham is important, because it can help relate flavor compounds to sensory descriptors and consumer preference as well as help monitor flavor quality.

To fully comprehend the nature of dry-cured ham flavor, a sensory language (lexicon) must be established through sensory descriptive analysis in order to differentiate and describe dry-cured ham products based on their flavor, aroma, and textural attributes (Armero et al., 1999; Flores, Ingram, Bett, Toldrá, & Spanier, 1997b; Ruiz, Ventanas, Cava, Timón, & García, 1998). Previous studies have related chemical information to the sensory proper-

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ties of dry-cured ham flavor (Buscailhon et al., 1994; Careri et al., 1993; Flores et al., 1997a). However, none of these studies identified which sensory attributes or volatile flavor compounds characterize certain dry-cured ham products and how intensity and presence of sensory attributes and/or volatile compounds relate to consumer acceptability. A lexicon used to describe Serrano ham was grouped into three factors such as "cured flavor", "off-flavor" and "pork flavor" and indicated higher intensities for these factors in its longer aged hams. Iberian hams that were ripened by the longer aging process also had higher intensities for "cured flavor", "aftertaste" and "flavor strength" when compared to short-aged hams.

The objective of this research was to determine the relationships between objective sensory descriptors, consumer acceptability and volatile flavor compound composition of American dry-cured ham. This objective was met through identifying the sensory characteristics that describe and differentiate American dry-cured ham, identifying the volatile and the aroma impact compounds in American dry-cured ham using solid phase microextraction (SPME)-gas chromatography–mass spectrometry (GC–MS) and SPME-Osme-gas chromatography olfactometry (GCO), and utilizing preference mapping to explain the relationships between common sensory descriptors, consumer acceptability, and volatile flavor compounds.

2. Materials and methods

2.1. American dry-cured hams

Eight dry-cured ham products (Table 1) with varied aging periods and cure ingredients were purchased from six manufacturers at three different processing times within the year. Seven of the hams were purchased as slices and one ham was purchased whole. These samples were carefully selected by two experienced dry-cured ham researchers giving a good representation of the variety in dry-cured hams within the United States based on regional locations and flavor preferences. These products make up greater than 50% of the hams that are produced in the United States, and the manufacturers that make these hams are among the largest producers of dry-cured hams in the United States. Five hams underwent a processing period of 90–180 days (short process), which consisted of curing (2 days per pound of uncured weight, 2–4 °C), cure equalization (14 days, 10–13 °C), smoking (1 day, 31–33 °C) and aging (40–130 days, 29–32 °C). The remaining hams were aged by means of the long process with a processing period of either 180–270 days or 270–360 days. Only center ham slices (6 ± 1 mm), which consisted of the *Biceps femoris*, *Semitendinosus* and *Semimembranosus* were used. Dry-cured ham slices were separated, individually vacuum packaged (Model HVT-30, Hollymatic Corp., Countryside, IL) in high performance bags (Vacuum Pouches, KOCH Supplies Inc., Kansas City, MO) and stored at 4 °C until subsequent analyses were performed. Stored samples were used within a period of one month.

Table 1
Process specifications of dry-cured hams from various regional locations

Ham	Processing period	Curing information[c]	Smoked
1SHORT	3-6 mos	Salt	Yes
2SHORT[a]	4–6 mos	Salt	Yes
3SHORT	3–6 mos	Salt	Yes
4SHORT[b]	4–6 mos	Salt	Yes
5SHORT	4 mos	Salt	Yes
1LONG[a]	10–12 mos	Salt	Yes
2LONG[b]	9–12 mos	Salt	No
3LONG	9 mos	Salt	No

[a–b] Dry-cured hams with the same letter denote the same processor.
[c] Additional ingredients are withheld for proprietary reasons.

2.2. Chemicals

The following chemical standards were obtained to verify gas chromatographic results: methanethiol, carbon disulfide, 2-butanone, 3-methylbutanal, hexanal, 2-furanmethanol, 2-heptanone, methional, 1-octen-3-ol, benzaldehyde, limonene, benzeneacetaldehyde, 2-methoxyphenol, 4-methyl-2-methoxyphenol, 4-ethyl-2-methoxyphenol and 2,6-dimethoxyphenol (Sigma–Aldrich Chemical Co., Milwaukee, WI). An internal standard (chlorobenzene, 200 ppm) and an *n*-alkane series C_5–C_{18} (Sigma–Aldrich Chemical Co., Milwaukee, WI) were used to standardize the results and calculate Linear Retention Indices (LRI). Deionized water (Fisher Scientific Company LLC, Middletown, VA) with a pH of 7.0 (20 °C) was used to prepare dry-cured ham homogenates.

2.3. Sample preparation

Ham slices were equilibrated to room temperature (20 °C), wrapped in extra heavy-duty foil bags (Reynolds™, Alcoa Consumer Products, Alcoa Inc., Richmond, VA) and placed on a metal baking pan for support. Slices were cooked in an electric oven (Model JBP25DOJ2WH, General Electric, Louisville, KY) at 177 °C to a surface temperature of 66 ± 3 °C, which was monitored using a non-contact infrared thermometer (Model IT-330, Horiba, Kyoto, Japan). This cooking method was adapted from the manufacturer's specifications to represent normal consumer use and to minimize variation in the cooking process. Skin and subcutaneous and intermuscular fats were trimmed from the oven-baked ham slices prior to analytical and sensory analyses.

2.4. Descriptive sensory analysis

Eight dry-cured hams were assessed by a panel of seven members with greater than 100 h of experience (per panelist) pertaining to the evaluation of meat products. A total of three sessions were conducted in a span of 3 mos. and eight hams were evaluated in every session. Quantitative descriptive analysis (QDA®) was conducted in all sessions (Meilgaard, Civille, & Carr, 1999). The panelists participated in training sessions which totaled more than 20 h with a minimum of 3 h for each dry-cured ham sample. Previously identified descriptors (Table 2, Armero et al., 1999; Civille & Lyon, 1996; Ruiz et al., 1998) and terms generated during training were utilized for the sensory evaluation of dry-cured hams. Panelists individually formed a descriptive profile for each sample under fluorescent lighting in a well ventilated room with positive pressure and temperature control. Next, the panelists developed a lexicon of descriptors to ensure consistency in the application of these descriptors. The descriptors were rated using a 15-point intensity line scale, where 0 = not detected and 15 = extremely strong with respect to the sensory attributes.

Oven-baked, thin dry-cured ham slices were cut into 2.54 cm × 2.54 cm pieces, placed in gallon-sized plastic bags (Ziploc™ brand bags, S.C. Johnson and Son Inc., Racine, WI) and stored in a water bath (60 °C) for 10–15 min until sensory evaluations could be performed. Dry-cured ham pieces were served in 2-oz. plastic containers with lids (Sweetheart Cup Co., Owing Mills, MD) and coded with random three-digit numbers. Each panelist received four pieces of each ham for every session. This was carried out to ensure that the dry-cured hams were maintained at the same temperature throughout the evaluation. The order of presentation of the samples was randomized to consider the effect of rank. Panelists were provided with water (Mountain Spring Water,