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Simultaneous analysis of consumer variables, acceptability and sensory characteristics of dry-cured ham

Masahiro Sugimoto [a,*], Shinichi Obiya [b], Miku Kaneko [a], Ayame Enomoto [a], Mayu Honma [a], Masataka Wakayama [a], Masaru Tomita [a]

[a] Institute for Advanced Biosciences, Keio University, Tsuruoka, Yamagata 997-0052, Japan
[b] Tohoku Ham, Tsuruoka, Yamagata 997-0011, Japan

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ABSTRACT

We conducted a consumer acceptability analysis of dry-cured ham based on sensory evaluation. Consumer acceptability data are rendered heterogeneous by the diverse backgrounds and assessment abilities of the participants, requiring versatile analytical methods for their interpretation. Totally, 9 sensory attributes of 12 kinds of dry-cured ham samples collected from Japan ($n = 9$), Italy ($n = 1$), Spain ($n = 1$), and Germany ($n = 1$) were tasted by 117 Japanese consumers who showed acceptable evaluation abilities during blind sampling. Common techniques, such as hierarchical clustering, principal component analysis, and external preference mapping, were simultaneously utilized to analyze each characteristics scored in modified hedonic scale. These analyses revealed the relationships between the features and preferences of the assessors. For example, consumers aged 20–30 with smoking and drinking habits preferred sweetness and saltiness, and gave high ratings to Spanish Jómon serrano and Italian prosciutto. Our approach could assist ham marketers to identify potential purchasers and the preferred characteristics of their products.

1. Introduction

The design of processed foods such as dry-cured ham requires sophisticated branding strategies based on consumer preferences, inducing consumers to accept and select the products. Sensory evaluation tests are important for assessing the sensory attributes of a product, and are used in the quality control and design of new products, especially in the developmental stages (Muñoz, 2002). However, sensory evaluation data are complicated by many factors, such as sensory preferences, product features and the diverse backgrounds of consumers. Dried-cured ham requires a long ripening process and incurs large costs. Therefore, information regarding attractive package design and product design obtained by sensory evaluation is important for the production of this item (Morales, Guerrero, Aguiar, Guardia, & Gou, 2013).

Sensory evaluation tests of dry-cured hams have been reported in several studies. For example, to investigate the relationship between physico-chemical and the sensory features of dry-cured hams, Laureati et al. (2014) compared the sensory attributes of Italian Parma, San Daniele and Toscano hams using imaging analyses and electronic nose tests. The short-term effects of freezing and boning on the limbs have been investigated from the chemical and physical features of hams, such as total protein, pH, and color (Tomovic et al., 2013). The same features, along with the ripening duration, have been determined from the salt and moisture profiles of Italian dry-cured hams (Benedini, Parolari, Toscani, & Virgili, 2012). The effect of salty water on Iberian hams has been determined by peptidase activity assay (Flores, Aristoy, Antequera, Barat, & Toldra, 2012). The ripening duration and flavor of Spanish Serrano has been evaluated by profiling the volatile compounds in the product (Flores, Grimm, Toldrá, & Spanier, 1997). The effect of storage and packaging on ham quality has also been analyzed (Nunez de Gonzalez et al., 2009). Because these studies investigated only the effects of storage and the processing parameters, their comparative designs were relatively simple and the data were interpretable by conventional statistical methods.

To maximize the utility of sensory evaluation, the relationship between the assessors' preference and product's sensory descriptions should be analyzed by mathematical modeling. However, because these relationships are multivariable vs. multivariable, they are difficult to interpret by conventional statistical analysis. Instead, to facilitate understanding of the inter-variable relationships, we can extract information on the pertinent variables by data mining techniques. This century, conventional statistical approaches have been supplemented with sophisticated data mining techniques such as Random forest (Granitto, Gasperi, Biasioli, Trainotti, & Furlanello, 2007), Support Vector Machine

* Corresponding author at: Institute for Advanced Biosciences, Keio University, 246-2 Kakuganji, Tsuruoka, Yamagata 997-0052, Japan.
E-mail addresses: msugi@sfc.keio.ac.jp (M. Sugimoto), s-obiya@tohokuham.co.jp (S. Obiya), kkk-miku@ttck.keio.ac.jp (M. Kaneko), ayame.e@ttck.keio.ac.jp (A. Enomoto), mayu-125@ttck.keio.ac.jp (M. Honma), wakayama@ttck.keio.ac.jp (M. Wakayama), mt@sfc.keio.ac.jp (M. Tomita).

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(Cortez, Cerdeira, Almeida, Matos, & Reis, 2009), Support Vector Regression (Sugimoto et al., 2010), and Partial Least Squares (PLS) (Ruiz, Garcıa, Muriel, Andrés, & Ventanas, 2002). These techniques are now popularly used to analyze the quantitative sensory descriptors of various foods.

The analysis of consumer acceptability and expectation is more complicated. Although the ratings of professional panelists and consumers are consistent overall, consumers' preferences are more heterogeneous (Resano, Sanjuan, Cilla, Roncales, & Albisu, 2010). Such heterogeneity can be reduced by limiting the assessors to those from specific backgrounds, such as income and education levels. However, more versatile approaches are necessary to explore consumers' demands. Preference map (PREFMAP) is a popular tool for analyzing consumer preferences and/or product features. For example, ice cream with/without reduction of fat and sugar contents (Cadena, Cruz, Faria, & Bolini, 2012), various dolce de leche commercially available in Brazil (Gaze et al., 2015), and dry fermented sausage with various ion content patterns (Dos Santos, Campagnol, Cruz, et al., 2015), and the pattern of volatile compounds in eight American dry-cured hams was determined in this way (Pham et al., 2008). These authors established relationships between the volatile compounds in the hams and their sensory features. Morales et al. (2013) employed PREMAP in a conjoint analysis of the appearances and consumer sensory preferences of dry-cured hams, focusing on the product features of the hams (such as sensory attributes and appearance).

Dry-cured ham is a popular food and has a long history in the Mediterranean region. In contrast, meat consumption in Japan has emerged only within the past 150 years. The Western meat-eating culture has popularized the eating of processed meat in Japan, including dried-cured hams (Sakata, 2010). Panelists of different nationalities generally show the same preferences, but may disagree in their odor and flavor preferences (García-González et al., 2006), and Japanese consumers show variable preferences for Japanese hams.

This study aims to understand how the sensory attributes of hams produced in Japan differ from those of European hams. To this end, we conduct a sensory evaluation of Japanese consumers. Integrating multiple data analysis methods such as hierarchical clustering (HCL) and PREFMAP, we simultaneously evaluate the relationship among (1) the sensory descriptors of ham, (2) assessor preferences, and (3) consumer features (e.g. smoking and drinking behaviors).

2. Material and methods

2.1. Sample information

The test samples were twelve kinds of dry-cured ham in two processing categories; non-smoked ($n = 7$) and smoked ($n = 5$). The samples included 3 European ham products, including a Prosciutto (Galloni, Parma, Italy), a Jómon serrano (Espuña, Olot, Spain), and a Black forest in German (Wein, Freudenstadt-Musbach, Germany) and 9 products from 3 ham manufactures in Japan (Kyodo International Inc., Kanagawa, Japan, and Tohoku Ham, Tsuruoka, Japan) (Table 1).

Table 1
Sample information.

No.	Country	Region	Type	Smoked
1	Japan	Tohoku	Jómon serrano	No
2	Italy	–	Prosciutto	No
3	Japan	Tokyo	Jómon serrano	No
4	Spain	–	Jómon serrano	No
5	Japan	Hokkaido	Prosciutto	No
6	Japan	Tohoku	Long ripened ham	No
7	Japan	Hokkaido	Processed ham	No
8	Japan	Tohoku	Rollschinken	Yes
9	Japan	Tohoku	Lachsschinken	Yes
10	German	–	Black Forest	Yes
11	Japan	Tohoku	Rohschinken	Yes
12	Japan	Tohoku	Rollschinken	Yes

2.2. Sensory evaluation

Accessors were recruited as volunteers in academic and commercial institutions in our region by distributing announcement of e-mail including research purpose and plans. The evaluated sensory attributes (listed in Table 2) included appearance (three attributes), flavor (one attribute), taste (three attributes), texture (two attributes), and total acceptance (one attribute). Although there are several scoring systems, such as just-about-right scale that evaluates sensory characteristics based on the difference of ideal points, in this study, each descriptor was scored on a Hedonic scale (Resano et al., 2010) with some modifications. Each scorer rated the samples on a 5-point scale from 1 (lowest) to 5 (highest), instead of 9 points used by original Hedonic scale. Opposite characteristics were assigned, e.g. the reddest and the most not red were 5 and 1, respectively, for evaluating appearance of the meat. All sensory attributes of the 12 ham samples (labeled No. 1–12) were evaluated relative to a reference sample (labeled No. 13), whose scores were all assigned as 3. To facilitate understanding of these hedonic scores, the rating system was described on the score sheet distributed to the assessors along with the ham samples. The ages, sexes, and smoking and drinking habits of the assessors were also collected.

The layout of the ham samples in the sensory evaluation test is depicted in Fig. S1. The 12 kinds of ham sample used in the sensory evaluation test were arranged on 14 trays. Bind test sample was arranged on 2 trays and reference samples were also arranged on 2 tray samples. Each sample was labeled only with its number. Wood-made chopsticks were provided. To cancel the aftertaste, assessors were provided with a bottle of mineral water (Tohoku-reizo, Yamagata, Japan) and cracottes (Asahi Food, Saitama, Japan).

Hams were obtained as a chunk, cut by a knife and immediately transferred to small trays. Each tray was covered by plastic wrap to prevent the diffusion of flavor. Prior to sensory evaluation, the ham samples were stored at 4 °C and prepared within 2.5 h of consumption. The sensory evaluation was conducted at 16:30 for 2.5 h in a large classroom. Room temperature was not controlled by air conditioning. Participants were allowed to remove the samples from the room, and therefore, they evaluated the samples under various conditions.

2.3. Data analysis

2.3.1. Assessment of evaluation ability

To access the evaluation abilities of the assessors, we compared the marked scores of identical samples No. 9 and No. 13. The score distributions of No. 9 were plotted as a histogram and participants with outlier ratings were excluded from subsequent analyses. First, marked scores of each descriptor were described in bar graph with average and standard deviations. Second, variation of difference between marked scores and expected score was confirmed and descriptors treated as outliers were selected. Thirdly, the sum of marked scores except for outliers was plotted as histogram based on 0.5 scale.

2.3.2. Data mining of sensory evaluation scores and consumer features

Consumers showing similar preferences in all collected descriptors were grouped by hierarchical clustering (HCL). The relationships among the ham sensory features and consumer preferences were visualized on a preference map. Here, the dimensions of the collected data were reduced by principal component analysis (PCA), which preserves the variance in the data, and visualizes the data in two-dimensional (2D) space. To understand the above relationships, the consumers grouped by HCL were overlaid on the 2D data. Both of them are categorized into unsupervised methods to evaluate overall similarity or discrepancy between samples; HCL is a method of cluster analysis to seek a hierarchy of cluster and PCA convert a set of observations into the