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Classification of traditional Chinese pork bacon based on physicochemical properties and chemometric techniques

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ABSTRACT

Sixty-seven pork bacon samples from Hunan, Sichuan Guangdong, Jiangxi, and Yunnan Provinces in China were analyzed to understand their geographical properties. Classification was performed by determining their physicochemical properties through chemometric techniques, including variance analysis, principal component analysis (PCA), and discriminant analysis (DA). Results showed that certain differences existed in terms of nine physicochemical determinations in traditional Chinese pork bacon. PCA revealed the distinction among Hunan, Sichuan, and Guangdong style bacon. Meanwhile, seven key physicochemical determination criteria were identified in line with DA and could be reasonably applied to the classification of traditional Chinese pork bacon. Furthermore, the ratio of overall correct classification was 97.76% and that of cross-validation was 91.76%. These findings indicated that chemometric techniques, together with several physicochemical determination, were effective for the classification of traditional Chinese pork bacon with geographical features. Our study provided a theoretical reference for the classification of traditional Chinese pork bacon.

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1. Introduction

Pork bacons are a class of traditional meat products in China. According to the Columbia Encyclopedia, bacon is made of hog flesh, particularly from the sides, belly, or back, that has been preserved by being salted or pickled and then dried with or without wood smoke. Traditional Chinese pork bacon possesses a long history in China, especially in the southern part, because of its distinct flavor, such as tangy, delicate, meaty, and salty, and its particular texture that appeals to Chinese consumers. At present, traditional Chinese pork bacon is being introduced worldwide (Yu et al., 2008). A variety of Chinese traditional pork bacon styles exist in China, but Hunan, Sichuan, Guangdong, Jiangxi, and Yunnan styles are most widely known. The characteristics for each category are associated with the variety of pork reared in particular areas, the distinctive processing of products, climate, and dietary habit of most local residents.

Presently, more and more traditional Chinese products become labeled with their geographical origins. Geographical classification is helpful for branding strategy purposes to help consumers select their food items (Ariyama et al., 2012). As a representative traditional Chinese meat product, numerous categories of traditional Chinese bacon can be included, and their characteristics are closely related to their production areas. Classifying the different styles of traditional Chinese pork bacon is important to qualify the particular aroma, taste, and special nutritional properties these varieties possess that make them preferable for more consumers (Cubadda et al., 2006; Galgano et al., 2008; Joebstl et al., 2010; Kelly et al., 2005; Lo Feudo et al., 2010; Spalla et al., 2009). Recent developments in chemometric techniques present great use in characterizing and classifying food products (Arvanitoyannis et al., 2005; Berrueta et al., 2007; Cantarelli et al., 2011; Chudzinska & Baralkiewicz, 2011; Kelly et al., 2005; Popek, 2002; Tzouros & Arvanitoyannis, 2001). Several analytical methods, such as principal component analysis (PCA) and linear discriminant analysis (LDA), have been applied as comprehensive methods based on chemometric techniques to analyze the classification of honey and determine of the geographic origin of rice, potatoes, olive oil, and Pecorino cheese, as well as to discriminate sweet wines (Ariyama et al., 2012; Benincasa et al., 2007; Cevoli et al., 2011; Di Giacomo et al., 2007; García-Martínez et al., 2011; NozalNalda et al., 2005). The physicochemical properties of Guangdong-style traditional Chinese pork bacon have been analyzed by several researchers. However, similar analyses have yet to be used in other styles of traditional Chinese pork bacon, so the physicochemical properties of other styles have not been understood to date. In particular cases, Krauze and Zalewski (1991) used principal component analysis to evaluate certain physicochemical characteristics as implements for the classification of honey from different botanical origins. In addition, 13 common physicochemical determination methods of honey samples from the various production zones of three styles in western Spain were analyzed for their geographical classification. Classifications of 70.1% and 76.0% were correctly made using discriminate analysis

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(Gómez Bárez et al., 2000; Krauze & Zalewski, 1991). However, few reports focused on the classification of traditional Chinese bacon, and classification methods are unavailable. Thus, selecting products according to their preference when purchasing becomes difficult for customers. Thus, establishment of a method or system to identify different styles of traditional Chinese pork bacon is necessary. The application of physicochemical determination methods combined with chemometric techniques can classify traditional Chinese bacon into five different styles and provide a discriminate equation as a standard database for bacon classification. However, these methods have not been currently used for Chinese pork bacon. The present study aims to classify traditional Chinese traditional pork bacon manufactured in five provinces of south China through physicochemical determinations. Given the varieties of pork, products processed in different areas, climates, and personal taste preferences of native citizens affecting the physicochemical properties of traditional Chinese bacon, nine physicochemical determinations, used as evaluation indicators for traditional Chinese bacon, were examined for subsequent classification. The application of PCA and DA to physicochemical determination properties will be used for classifying five different styles of traditional Chinese pork bacon and providing a discriminant equation as a standard database for the geographical classification of bacon.

2. Material and methods

2.1. Traditional Chinese pork bacon samples

A total of 67 different brand samples of traditional Chinese pork bacon were purchased at local commercial stores or exclusive shops in the provinces of Hunan, Sichuan, Guangdong, Jiangxi, and Yunnan (Table 1). The shelf life of the purchased samples was one month after product date. Each 500 g sample was sealed in vacuum packages and stored at 4 °C before testing.

2.2. Analytical determinations

The samples were ground for subsequent analysis, and nine physicochemical parameters, which included acid value, pH, peroxide value (POV), water activity (Aw), the contents of water, protein, fat, total sugar, and salt, were analyzed. The pretreatment method for the determination of acid value and POV complied with the Chinese Standard GB/T 5009.44 and the method for determination according to the Chinese Standard GB/T 5009.37. Water, fat (ether-extractable), and protein content were determined according to the Chinese Standard GB 50093-2010, GB/T 9695.7-2008, and GB 50095-2010 procedures using a hot air oven directly, Soxlet extraction apparatus, and a Kjeldahl assembly, respectively (Nisar et al., 2010). In addition to these properties, salt and total sugar content were determined on the basis of the Chinese Standard GB/T 9695.7-2008, GB/T 9695.31-2008 procedures with titrimetric analysis. The measurements of Aw were obtained using a water activity meter (Novasina, Switzerland). The measurements of pH were obtained using a digital pH meter (Sartorius, Germany). Minced meat samples were homogenized in pre-cooled distilled water with a polytron. After equilibration to room temperature the pH was recorded. For consistency, all experiments were performed in triplicates, and the results represented the mean values of three independent experiments.

Table 1
Number of samples and sampling regions of each bacon style.

Bacon styles	Number of samples	Sampling regions
Hunan	15	Changsha, Zhuzhou, Zhangjiajie Huaihua, Xiangtan Xiangxi, Changde, Yueyang
Sichuan	22	Chengdu, Chongqing, Guangan Mianyang, Dujiangyan
Guangdong	16	Guangzhou, Shantou, Zhongshan Dongguan, Foshan, Shenzhen
Jiangxi	6	Nanchang, Xiangping,Ganzhou Jiujiang, Jian
Yunnan	8	Kunming, Xuanwei,Yuxi, Dali Lijiang, Zhaotong

2.3. Data analysis

Statistical analysis of the data was carried out using SAS 9.2 and SPSS 17.0. An analysis of variance was performed (one-way ANOVA) as an initial explorative analysis for each physicochemical determination. Duncan's multiple comparison was employed to determine the significant differences in every style of bacon when the F value was significant in ANOVA. Afterwards, data were analyzed by multivariate chemometric techniques involving PCA and DA in the present data analysis. First, the purpose of PCA was dimension reduction and compression, in which the main factors (PCs) identified will account for most of the variability existing in the data matrix. PCA considers all variability and accommodates the total data structure, which is a method for exploratory data analysis. Second, DA, a supervised technique, was used to identify the known classification of several observations from others, to provide a discriminant model with physicochemical determinations, as well as to study the best classified traditional Chinese bacon among different styles. The stepwise selection process was used to eliminate the varieties from the models that fail to significantly contribute to the classification (Fraley & Raftery, 2002). Third, the prior probability uses “computing from the group size”, involving different numbers of Chinese traditional bacon samples from each style. The robustness of the classification model was estimated by a cross-validation test, utilizing the ‘leave-one-out’ procedure. In this operation, each of the cases was classified by the functions derived from all cases other than that particular case, and the availability of classification was recalculated by making comparison with the known case. Finally, DA provides discrimination functions for traditional Chinese bacon of each style (Liu et al., 2013).

3. Results and discussion

3.1. Difference analysis

Means, standard errors (SEM), and ranges for nine physicochemical properties are listed in Table 2, and the statistical differences of these parameters among styles were investigated using ANOVA. Results show that the acid value of Hunan-style bacon was the highest and that of Yunnan style bacon was the lowest among the five bacon styles. However, no significant difference ($P > 0.05$) was found for this value. Additionally, POV and the sugar content of Guangdong-style bacon were higher than those of others, exhibiting highly significant differences with the others ($P < 0.05$). As could be seen in Table 2, the fat content of Guangdong-style bacon was the highest but was not significantly different from the other four. By contrast, the water content of Guangdong-style bacon was lower than that of the remaining styles, with significant differences among samples, except between Hunan- and Jiangxi-style bacon and between Jiangxi- and Yunnan-style bacon. The mean values of protein content of all five styles ranged from 19.78% to 30.01%, with the lowest value from Jiangxi-style, and the highest from Hunan-style bacon. We understand the significance in characterizing and classifying the bacon varieties, particularly regarding the quality appraisal of bacon. This consideration was explained by the following facts. First, the quality of raw pork and meat selection from different parts of the swine's body generally presents dominant impacts on the fat, water, and protein content of the processed bacon. Thus, the differences of the results based on these parameters were significant ($P < 0.05$). Second, the parameters of traditional Chinese pork bacon were largely affected by processing techniques. For example, water content is affected by atmospheric climate in which the manufacturer is located. Sugar and salt content are affected by addition, and multiple

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