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Prediction of chemical composition and geographical origin traceability of Chinese export tilapia fillets products by near infrared reflectance spectroscopy☆

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ABSTRACT

Near infrared reflectance spectroscopy (NIRS) analysis was used to predict proximate chemical composition of Chinese export tilapia fillets from four geographical origins (Guangdong Province, Hainan Province, Guangxi Province and Fujian Province, respectively). NIRS provided good reliability in the prediction of chemical composition of tilapia fillets but weak results in crude protein prediction. Origin traceability is an important part of food safety traceability system. The tilapia origin traceability model was developed by near infrared reflectance (NIR) spectroscopy coupled with soft independent modeling of class analogy (SIMCA). The result showed that when classifying tilapia by means of SIMCA, more than 80% of from the Guangdong, Hainan and Fujian systems and 75% of fillets from the Fujian system were correctly and exclusively assigned to the correctly and exclusively assigned to the corresponding clusters. No spectra were assigned to two or more clusters, while a certain number of spectra (10–18%) were not assigned to any class. Only 1–2% of samples were classified incorrectly. The results of this study indicated that NIRS coupled with pattern recognition methods was a feasible way for origin traceability of export tilapia fillets.

1. Introduction

Tilapia fillet is one of important aquaculture fish products in the European Union. Trade in farmed tilapia from China to United States, Russia and the European Union is growing rapidly and becoming a significant component of Chinese export of aquatic products. Now, many fish productions are internationally traded with net flows from developing to developed countries. Growth in production and export of fish from Asia to European markets has accelerated over the last decade. The wide competition among producing countries in Asia and the consequent lowering of market prices are demanding the differentiation and characterization of tilapia fillet quality that has also occurred for other local foods. The different rearing systems and geographical origin used for tilapia production may affect flesh quality, especially in terms of fat concentration and quality. Moreover, prices often differ widely according to origin and are highest for wild fish.

Near infrared reflectance spectroscopy (NIRS) analysis may provide quick and wide information on food quality (Sun, Xu, & Ying, 2009), and has already been successfully used to predict the chemical composition of various fish and meats, such as salmon, mackerel, halibut, capelin and beef (Alomar, Gallo, Castañeda, & Fuchslocher, 2003; Cozzolino, Murray, & Scaife, 2002; Nortvedt, Torrissen, & Tuene, 1998; Solberg & Fredriksen, 2001), but less information is available on tilapia. Accurate analysis of fish composition is very important because of its relationship to both the quality and specific characteristics, such as eating quality and impact on consumer health. Over the past five years, a lot of feasibility studies on the application of NIRS to measurement of chemical composition in meat, seafood and many other foods have been reported (Weeranantanaphan, Downey, Allen, & Da-Wen, 2011). In the NIRS analysis of fish or any other food products, sample preparation technique is one of the main problems due to the high absorbance of the NIRS signal by water, which masks and

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disturbs information on the chemical constituents (Shenk, Workman, &Westerhaus, 1992).

As described by Downey (1996a), appropriate statistical treatment of NIR spectra permitted to identify the origin and characterize of a wide range of vegetal foods (from fruit juice to coffee). Although NIRS has been successfully used in some studies on vegetal foods (Chen et al., 2008; Woo, Kim, Ze, & Chung, 2005) and meat to identify species and some origins (Downey & Beauchêne, 1997; McElhinney, Downey, & Fearn, 1999; Olivier, Sinnaeve, & Dardenne, 2000), it has been applied only rarely to fish geographical identification and characterization. The aim of this study is to propose the use of NIRS combined with SIMCA to create tilapia origin traceability model, to provide new idea for origin traceability of meat.

2. Material and methods

2.1. The set of sample and chemical analyses

Over a 2-month period from October to December, 2010, tilapia fillets samples were obtained from four regions (Guangdong Province, Hainan Province, Guangxi Province and Fujian Province). The main characteristics of tilapia are summarized in Table 1.

Only one commercial size of tilapia fillet, 5–7 ounces, was selected from each region. These differences in number were imposed by the product available at the regions. The tilapia fillets were used for NIRS and chemical analyses. The fillets were analyzed for proximate composition following Chinese standard methods. Fat, protein and moisture contents in tilapia were in accordance with GB/T 9695.1-2008/ISO 1444: 1996 (Meat and meat products – Determination of free fat content), GB/T 9695.11-2008 (Meat and meat products – Determination of nitrogen content) and GB/T 9695.15-2008 (Meat and meat products – Determination of moisture content) respectively.

2.2. NIRS analysis

NIRS analysis was performed by a near infrared reflectance spectroscopy spectrometer (NIRFlex N-500, Büchi Labortechnik AG, Flawil, Switzerland) in the 4000 and 10,000 cm^{-1} range with a 4 cm^{-1} step. The number of scans was 64. Each fillet was analyzed according to the following sample: dorsal flesh. Each dorsal flesh sample was treated with meat grinder. Then the treated fish meat paste was put into specific petri dish. Scanning temperature of NIR was controlled in the 20 and 25 °C ranges. Calibration equations were calculated by partial least square regression (PLSR) to predict moisture (g/100 g), crude protein (g/100 g), and lipid (g/100 g) content. The number of factors used as independent variables in the prediction equations was fixed at a maximum of 20 in order to avoid over fitting (Shenk & Westerhaus, 1994). The optimal number of factors was chosen as a function of the first local minimum in the validation residual variance plot. Full cross-validation was used.

Prediction equations were evaluated in terms of coefficient of determination in calibration (R^2c) and cross-validation (R^2cv), standard error of calibration (SEC) and standard error of cross-validation (SECV).

Principal component analysis (PCA) was used to calculate models for four clusters of samples on the basis of the geographical system using full cross-validation. Soft Independent Modeling Class Analogy (SIMCA) was used to measure the model-to-model distance and classify samples by the geographical origin. Cluster membership in SIMCA was tested at $P < 0.05$ level. Both PCA and SIMCA were performed using BUCHINIR Cal 5.2 software.

Table 1
The geographical origin and feeding mode of tilapia.

Region	Longitude	Latitude	Sampling time	Number
Guangdong	110°31′	20°56′	2010.10–2010.11	58
Hainan	110°10′	19°58′	2010.11–2010.12	56
Guangxi	108°03′	22°08′	2010.12	48
Fujian	119°40′	27°28′	2010.12	46

3. Results

3.1. NIRS prediction of chemical composition

The proximate composition of the tilapia fillets were analyzed separately and averaged to obtain a reference value. Both moisture (60.9–80.2 g/100 g) and lipid (1.1–14.4 g/100 g) concentrations varied widely, while crude protein varied in a closer range (16.1–22.8 g/100 g). Table 2 showed the average and SD value of different sample sets.

Calibration and validation results for the prediction of chemical composition of tilapia fillets are reported in Table 3. Predictions of moisture and lipid calculated on the spectra of minced fillets showed high correlation both in calibration and cross-validation, while prediction of protein showed low correlation.

NIRS prediction of moisture concentration provided good coefficients of determination using dorsal flesh of tilapia samples in Calibration set and validation set ($R^2c = 0.95$ and $R^2cv = 0.95$) with a very low prediction error (SEC = 0.85 g/100 g and SECV = 0.87 g/100 g). The same accuracy was observed for lipid prediction in calibration set and validation set ($R^2c = 0.97$, $R^2cv = 0.97$, SEC = 0.68 g/100 g and SECV = 0.66 g/100 g). NIRS prediction of crude protein in tilapia fillets was less successful. Coefficients of determination gave fairly good results in Calibration set and validation set ($R^2c = 0.61$, SEC = 0.39 g/100 g, $R^2cv = 0.30$, SECV = 0.55 g/100 g).

The comparison of the chemical values and NIR predicted values of moisture and lipid were shown in Figs. 1 and 2. The abscissa was the measured value by chemical methods; and the ordinate was the calculated values by NIRS. From the two figures, we could find that all plot points were uniformly distributed in the line around, so the moisture and lipid prediction models were effective, that is, model forecasting capability is very good.

Randomly selected some model-outside samples were used for external validation of the model. The comparison of external validation results was shown in Tables 4 and 5. The largest relative

Table 2
Chemical composition of tilapia fillets.

	Moisture (g/100 g)	Crude protein (g/100 g)	Lipid (g/100 g)
Guangdong (*no. = 66*)			
Average	76.1	19.1	2.7
SD	1.5	0.6	1.5
Hainan (*no. = 65*)			
Average	70.7	19.1	8.5
SD	3.6	0.7	3.7
Guangxi (*no. = 50*)			
Average	67.6	19.3	10.8
SD	2.3	0.7	2.8
Fujian (*no. = 49*)			
Average	70.3	19.3	8.3
SD	1.7	0.6	2.1
All samples (*no. = 208*)			
Average	70.9	19.2	7.9
SD	3.8	0.7	3.9