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Research Article

Correlations between Texture Profile Analysis and Sensory Evaluation of Cured Largemouth Bass Meat (*Micropterus salmoides*)

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Texture is an important factor in evaluating the quality of aquatic products. To evaluate the texture properties of cured large mouth bass, edible sodium chloride (0, 1.0, 2.0, and 3.0%) was smeared to the bass meat. Texture profile analysis (TPA) and sensory evaluation were performed to evaluate the quality of the cured samples, and the correlations of the indexes in the two methods were analyzed. Two principal components were obtained from the TPA indexes and sensory evaluation indexes, and the cumulative variance contribution rates were 73.87% and 72.99%, respectively. Results from the principal component analysis showed that the main indicators that affected the TPA were gumminess and springiness, while those that affected sensory evaluation were chewiness and adhesiveness. The TPA index and sensory evaluation could be effectively improved when the sodium chloride added to the bass meat was 1%. In the correlation analysis, sensory springiness was negatively correlated with TPA hardness ($P < 0.05$, $r = -0.553$) but positively correlated with TPA chewiness ($P < 0.05$, $r = 0.596$). After stepwise regression analysis, the prediction equation between the sensory springiness and TPA hardness was obtained as SSp=5.770−0.002Ha. These results provide a basis for predicting the quality of large mouth bass cured products.

1. Introduction

Large mouth bass (*Micropterus salmoides*) is one of the important economic fishes in the coastal areas of China [1]. As an alternative for high-end freshwater fish consumption in China, bass is deeply loved by consumers. Current research on bass is not only limited to the growing dietary needs of humans but also involves the genetics and immunology of bass [2].

Texture is one of the most important indexes in identifying the quality of aquatic products [3]. At present, texture is primarily evaluated using sensory evaluation and texture profile analysis (TPA) [4]. Although sensory evaluation can reflect more directly and accurately the texture characteristics, such process has strict requirements for experimental programs and evaluators [5, 6]. Instrumental analysis can avoid the subjective influence of human factors on the evaluation results. This process is simple, convenient, and highly sensitive but easily affected by instrumental parameters [7]. Therefore, the comparison of sensory evaluation and instrumental analysis is very important to evaluate accurately and reasonably the texture characteristics of cured bass.

U-chupaj et al. conducted a Pearson correlation analysis on the sensory attributes of cooked chicken meat and TPA parameters. The results showed that TPA gumminess and hardness were positively correlated with the number of chews of sensory indicators but negatively correlated with juiciness [8]. Saldaña et al. found that the sensory hardness of traditional and light mortadella is positively correlated with the springiness of TPA [9]. Bland et al. calculated the TPA attributes of fresh-frozen and individual quick-frozen (IQF) catfish fillets based on the compression force curve generated by the two compressions of the ball probe. They also established the predictive equation for the attributes of sensory texture [10]. The study revealed that the sensory attributes of hardness were in the fresh TPA predictors in both freezing and IQF. In the above studies, TPA and sensory evaluation have been found to exhibit a certain correlation, and a statistically significant prediction equation can be obtained. However, the correlation between the two processes in the texture properties of fish cured products is rarely studied.

Therefore, we performed instrumental analysis and sensory evaluation of cured bass meat with different amounts of sodium chloride added and performed significant analysis and principal component analysis (PCA). This study can reveal the correlation between the sensory evaluation and instrumental analysis of the cured bass. In addition, a model for predicting the sensory properties of cured bass can be constructed through stepwise regression analysis to evaluate more correctly and reasonably the texture characteristics of bass meat.

2. Materials and Methods

2.1. Preparing Fish Samples. Fresh large mouth bass ($n = 20$) with a weight of 550–650 g and body length of 30–35 cm were purchased from Hubei Jiayu Sanhu Fishery Co., Ltd. The back meat on each side of the main bone of the pretreated bass was taken, washed, and drained. The back meat was then cut into 2 cm × 2 cm × 1 cm pieces with a surgical knife and fish pieces with equal mass was selected. A straight edge and a balance were used to accurately measure the size and the mass of those fish pieces. Edible sodium chloride (0, 1.0, 2.0, and 3.0% (w/w)) was smeared and spread evenly on the fish pieces, and the pieces were cured for 4 h by dry curing method. Preparing a stainless steel pot and appropriate amount of water, the water was heated in the pot to boiling until steam emerges. The cured bass meats were then steamed in the pot for 3 min to maintain their shape. TPA was performed, and the same indexes were assessed for sensory evaluation.

2.2. Instrumental TPA. The texture analyzer with P/36R probe (TA-XT Plus, Stable Micro System, UK) was used to measure the hardness, springiness, chewiness, adhesiveness, and gumminess of the samples [10, 11]. The parameters to analyze the texture were as follows: strain, 50%; pretest speed, 2.0 mm/s; test speed, 1.0 mm/s; posttest speed, 5.0 mm/s; and time, 5.0 s. During the test, six or seven duplicate samples were prepared in each group and the triplicate samples in each group with the closest size and quality are measured. Each parallel sample was tested twice. The results were collected and recorded.

2.3. Sensory Evaluation. The sensory analysis adopted the texture profiling, and the specific sensory evaluation method was as described in GB/T16860-1997 and related reports [12, 13]. The evaluation team consisted of 10 well-trained personnel who had healthy oral environment and were interested in sensory analysis. The evaluation criteria are listed in Table 1. During the sensory evaluation, the samples were blindly labeled to avoid the group members' bias due to different factors. Ten group members scored the samples item by item. The sensory score was the arithmetic average after removing the highest and lowest scores.

2.4. Data Analysis. Origin 2019 (Northampton, MA, USA) and IBM SPSS Statistics 26.0 software (IBM Corporation, New York, USA) were used for mapping and statistical analysis. One-way ANOVA with Duncan's program was used to analyze the differences among the data of different sodium chloride concentrations in the sensory evaluation and instrumental analysis. The data were expressed as mean ± standard deviation, and the difference was considered significant at $P < 0.05$. Factor analysis and PCA were performed to analyze the texture characteristics of the cured bass meat. Pearson correlation coefficient was calculated to analyze the correlation between the sensory evaluation indexes and instrumental indexes. The equation for predicting the main texture characteristics of bass meat was established by stepwise regression analysis.

3. Results and Discussion

3.1. Instrumental TPA. As shown in Table 2, with the increase in sodium chloride concentration, the TPA parameters showed collinear variation [14], the hardness and adhesiveness of bass meat increased, but the springiness, chewiness, and gumminess significantly decreased ($P < 0.05$), compared with the control group. Previous studies have shown that the meat hardness is related to the sodium chloride content; that is, the higher the sodium chloride concentration is, the greater the hardness of fish meat will be [15,16], which is consistent with the results in the current study. This phenomenon may be related to the rapid water loss of myofibrin in fish as a result of the osmotic dehydration caused by NaCl, leading to the decrease in the water content of bass meat [17–19].

3.2. Sensory Evaluation. As shown in Table 3, the hardness, adhesiveness, and chewiness of bass meat in the sodium chloride group increased significantly ($P < 0.05$), but the springiness decreased significantly ($P < 0.05$), compared with the control group. This phenomenon may be related to the denaturation of the fish protein due to the marinade in the curing process, resulting in the decrease of their gel properties and increase in the toughness of the fish tissue structure [20]. With the increase in sodium chloride content, the trends of hardness, adhesiveness, and springiness of bass meat in this sensory evaluation were consistent with the TPA results, but the trends of chewiness and gumminess were contrary to the TPA results. The reason may be the difficulty in the accurate quantification and direct determination of the chewiness and gumminess in TPA from the obtained force/time graph [21].

Table 1: Definition and evaluation criteria of the indexes in sensory evaluation.

Index	Evaluation method	Object of reference	Scores
Hardness	The sample was placed between the molars (the teeth on both sides of the back of the mouth) and chewed evenly to evaluate the force required to compress the food.	Cream cheese	1
		Franconian sausage	3
		Peanut	6
		Fruit hard candy	9
Adhesiveness	The sample was pressed between molars and the amount of deformation before fracture was evaluated.	Corn cake	1
		American cheese	5
		Sandwich bread	7
		Seedless raisins	10
		Chewing gum	15
Springiness	The sample was placed between the molar teeth and subjected to local compression. The compression was cancelled, and the speed and degree of deformation recovery were evaluated.	Cream cheese	0
		Franconian sausage	3
		Marshmallow	6
		Jelly	9
Chewiness	The sample was placed in the mouth and chewed once per second. The force required was the same as that required to bite through a piece of gum within 0.5 s. The number of chewing times when the sample could be swallowed was evaluated.	Cream cheese	1
		Young wheat bread	3
		Graham crackers	6
		Marshmallow	9
Gumminess	The sample was placed in the mouth and played between the tongue and the roof of the mouth to assess the force required to disperse the food.	Very easy to disperse	1
		Easy to disperse	3
		Generally	5
		Hard to disperse	7
		Very hard to disperse	9

Table 2: TPA indices (mean ± SD) of *Micropterus salmoides* products with different sodium chloride additions.

Sodium chloride (%)	Hardness (g)	Adhesiveness (g.s^{-1})	Springiness	Chewiness (g)	Gumminess (g)
0	874.77 ± 91.41^{a}	−4.98 ± 1.40^{a}	61.39 ± 1.42^{c}	255.65 ± 7.78^{b}	386.03 ± 39.71^{b}
1	876.06 ± 51.25^{a}	−3.64 ± 1.50^{a}	53.93 ± 1.19^{b}	177.38 ± 65.45^{a}	349.30 ± 109.33^{b}
2	911.17 ± 193.51^{a}	−2.82 ± 3.43^{a}	56.31 ± 2.32^{b}	156.63 ± 62.87^{a}	236.75 ± 41.20^{a}
3	1054.87 ± 118.35^{a}	−3.40 ± 2.20^{a}	49.95 ± 4.23^{a}	144.89 ± 45.85^{a}	178.55 ± 85.30^{a}

The data are the means ± standard deviation. Superscripts with different letters in the same column indicate significant differences ($P < 0.05$).

Table 3: Sensory indexes (mean ± SD) of *M. salmoides* products with different sodium chloride concentrations.

Sodium chloride (%)	Hardness	Adhesiveness	Springiness	Chewiness	Gumminess
0	2.10 ± 0.30^{a}	3.30 ± 0.46^{a}	3.8 ± 0.40^{c}	3.9 ± 0.30^{a}	3.2 ± 0.40^{a}
1	2.80 ± 0.40^{b}	3.70 ± 0.46^{ab}	3.2 ± 0.60^{b}	4.7 ± 0.64^{b}	3.8 ± 0.60^{b}
2	3.20 ± 0.40^{c}	4.00 ± 0.45^{b}	2.7 ± 0.46^{a}	4.7 ± 0.46^{b}	3.8 ± 0.40^{b}
3	3.80 ± 0.40^{d}	4.50 ± 0.50^{c}	2.3 ± 0.46^{a}	4.3 ± 0.46^{ab}	3.3 ± 0.46^{a}

The data are the means ± standard deviation. Superscripts with different letters in the same column indicate significant difference ($P < 0.05$).

It is not conducive to the accurate evaluation of bass quality because of the collinearity among the different texture indicators. To evaluate the contribution of each index to the texture characteristics of bass and accurately evaluate the texture characteristics of the sample quality, PCA and index correlation analysis were performed.

3.3. PCA. In the PCA, Table 4 shows that f_1–f_5 are the principal component factors of TPA, and those for sensory evaluation are F_1–F_5. The cumulative contribution rate of f_1 and f_2 reached 73.87% and that of F_1 and F_2 reached 72.99%. The first two principal factors can explain most of the texture of the fish samples [22]. Therefore, f_1 and f_2 were selected to represent the overall information for the TPA indicators and F_1 and F_2 for the sensory evaluation of the bass samples. The orthogonal rotation method was adopted to rotate the TPA and sensory principal component factors [23], and the characteristic vector coefficients of each index were calculated. Equations (1) and (2) were obtained for the TPA index and f_1 and f_2 of the sample, while those for the sensory evaluation were equations (3) and (4).

Table 4: Total variance for the TPA and sensory evaluation.

PCF	TPA			PCF	Sensory evaluation		
	Λ_E	R_{VC} (%)	R_{CVC} (%)		Λ_E	R_{VC} (%)	R_{CVC} (%)
f_1	2.355	47.103	47.103	F_1	2.319	46.387	46.387
f_2	1.338	26.768	73.871	F_2	1.330	26.607	72.994
f_3	0.565	11.294	85.165	F_3	0.619	12.383	85.377
f_4	0.400	7.997	93.162	F_4	0.434	8.678	94.055
f_5	0.342	6.838	100.000	F_5	0.297	5.945	100.000

PCF represents the principal component factors in PCA. Λ_E represents the eigenvalues obtained by PCA. R_{VC} indicates the rates of variance contribution obtained by PCA. R_{CVC} indicates the rates of cumulative variance contribution obtained by PCA.

$$f_1 = -0.140x_1 - 0.222x_2 + 0.192x_3 + 0.231x_4 + 0.147x_5, \tag{1}$$

$$f_2 = 0.432x_1 + 0.218x_2 + 0.350x_3 - 0.098x_4 + 0.439x_5, \tag{2}$$

$$F_1 = 0.243X_1 + 0.225X_2 + 0.236X_3 - 0.135X_4 + 0.049X_5, \tag{3}$$

$$F_2 = -0.081X_1 - 0.269X_2 + 0.023X_3 - 0.439X_4 + 0.542X_5. \tag{4}$$

where x_1–x_5 represents the hardness, adhesiveness, springiness, chewiness, and gumminess during the TPA analysis; and X_1–X_5 represents the corresponding indexes for the sensory evaluation.

According to the eigenvector coefficients of equations 1 and (2), among the TPA parameters, the chewiness and adhesiveness of f_1, as well as the gumminess and hardness of f_2, had higher loads. From equations 3 and (4), for the sensory evaluation, the hardness and springiness in F_1, as well as the chewiness and gumminess in F_2, showed higher loads.

3.4. Principal Component Loading Analysis. The principal component load diagrams were drawn using the scatter method as shown in Figures 1 and 2, in which the abscissa and the ordinate represent the f_1 and f_2 of TPA, as well as F_1 and F_2 for the sensory evaluation, respectively. The principal factor load reflects the magnitude of the contribution rate of each index to the principal factor, and the distance from the index to the origin is positively correlated to the contribution rate of the variables. The farther the distance between the index and the original point in the diagram, the higher the degree that its variables are introduced by the principal factor [24]. Therefore, the distance (d_i) of each TPA factor to the origin was calculated and ordered, and the results were as follows: gumminess, $d_5 = 0.6900$; springiness, $d_3 = 0.6698$; hardness, $d_1 = 0.6634$; adhesiveness, $d_2 = 0.6064$; and chewiness, $d_4 = 0.5623$. Thus, gumminess and springiness in the TPA were the main indexes that reflect the texture characteristics of cured bass. Combined with Table 2, the springiness of cured bass decreased with the increase in sodium chloride concentration, while the gumminess increased with the sodium chloride concentration. These phenomena may be due to the fact that during sodium chloride curing, the water exudation of the bass meat strengthened the interaction between the protein molecules, which shrunk the fish tissue to a certain extent [25].

The distance (d_i) of each sensory evaluation factor to the origin was calculated and ranked, and the results were as follows: chewiness, $d_4 = 0.6538$; adhesiveness, $d_2 = 0.6495$; gumminess, $d_5 = 0.6319$; hardness, $d_1 = 0.5753$; and springiness, $d_3 = 0.5478$. Therefore, chewiness and adhesiveness were the main indicators that reflect the sensory evaluation of the texture characteristics of cured bass. As shown in Table 3, the higher the sodium chloride concentration, the higher was the chewiness. This phenomenon was also observed in the hardness and may be related to the reduction in moisture by osmosis. According to the above results, optimal texture characteristics were obtained when the sodium chloride concentration was 1%.

3.5. Correlation Analysis. According to Table 5, sensory springiness was highly correlated with hardness and chewiness in TPA, but sensory hardness, adhesiveness, chewiness, and gumminess had less correlation with the TPA indicators. A significant negative correlation ($P < 0.05$, $r = -0.553$) was found between the sensory springiness and TPA hardness, which agreed with previous findings that a certain correlation existed between the TPA hardness and sensory evaluation indexes [26]. Sensory springiness was significantly correlated with TPA chewiness ($P < 0.05$, $r = 0.596$). Di Monaco et al. studied the texture properties of 15 kinds of food and found that there was no correlation between sensory springiness and springiness index measured by TPA [27]. Much ambiguity remains about the underlying principles and methods governing the instrument-sensory relationship in edible biomaterials, which may account for the low correlation between sensory springiness and TPA springiness [28]. Therefore, sensory springiness and the five indicators of TPA were analyzed by stepwise regression, and the corresponding prediction equation was obtained.

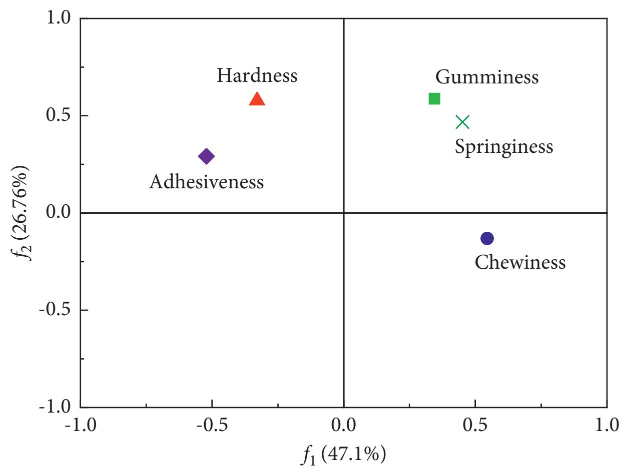

Figure 1: Biplot of the principal component analysis for the texture profile analysis.

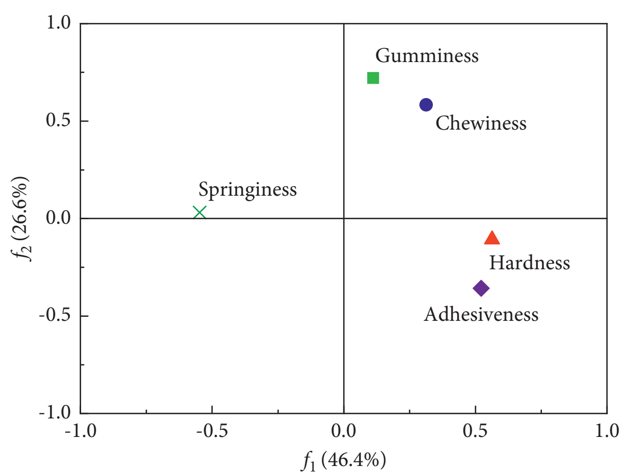

Figure 2: Biplot of the principal component analysis for sensory evaluation.

Table 5: Pearson correlation coefficients between the indexes of TPA and sensory evaluation.

TPA	Sensory evaluation				
	Hardness	Adhesiveness	Springiness	Chewiness	Gumminess
Hardness	0.197	0.117	−0.553*	0.280	0.241
Adhesiveness	0.204	−0.133	−0.396	0.091	−0.023
Springiness	−0.205	−0.195	0.260	−0.013	−0.374
Chewiness	−0.315	−0.072	0.596*	−0.270	−0.421
Gumminess	−0.252	−0.200	−0.077	−0.092	−0.110

*Significant at the 0.05 level (2-tailed).

Table 6: Result of the stepwise regression for the TPA parameters as functions of sensory attributes.

Descriptor	Multiple correlation coefficient®	Coefficient of determination (R^2)	Significance (F)	Prediction model
Springiness	0.553	0.306	0.011	SSp=5.770−0.002Ha

SSp, sensory springiness; Ha, TPA hardness.

3.6. Stepwise Regression Analysis. As shown in Table 6, the optimal regression model of sensory springiness with statistical significance ($P < 0.05$) was obtained, and the coefficient of determination R^2 of the equation was 0.306. Sensory springiness was not significantly different from the chewiness in the TPA, so this index was removed. Therefore, the prediction model of sensory springiness and hardness of TPA was obtained by stepwise regression analysis.

4. Conclusion

Differences were found among the data from the sensory evaluation and instrumental analysis of cured bass with various sodium chloride concentrations. After PCA, two principal components were obtained from the TPA indexes and sensory evaluation indexes, and the cumulative variance contribution rates were 73.87% and 72.99%, respectively. The main indexes reflecting the texture of cured bass in TPA were gumminess and springiness, while in the sensory evaluation, chewiness and adhesiveness were the main indexes. Combining the TPA results with those from sensory evaluation analysis showed that 1% was the optimal sodium chloride concentration to be added to the large mouth bass meat. Comprehensive analysis of the correlation between the TPA and sensory evaluation showed that sensory springiness was negatively correlated with TPA hardness but was positively correlated with TPA chewiness. The prediction model for sensory springiness and TPA hardness was obtained as $SSp=5.770-0.002Ha$ ($P < 0.05$). This model could predict the sensory springiness by TPA hardness.

Data Availability

The data in this study are contained within the article.

Conflicts of Interest

The authors declared that they have no conflicts of interest regarding any research, authorship, and publication in connection with the work submitted.

Authors' Contributions

Meijin Li curated the data and wrote the original draft. Meijin Li, Yanan Chen, and Hailan Li performed the formal analysis. Meijin Li, Jiajun Huang, Guangquan Xiong, and Hailan Li performed the investigation. Meijin Li, Yanan Chen, Xiaoyan Zu, Guangquan Xiong, and Hailan Li designed the study methodology. Meijin Li and Yanan Chen performed the software analysis. Meijin Li and Jiajun Huang performed the visualization. Xiaoyan Zu and Hailan Li acquired the funding. Xiaoyan Zu and Guangquan Xiong administered the project. Xiaoyan Zu provided the resources and wrote, reviewed, and edited the manuscript. Guangquan Xiong supervised the study. Hailan Li validated the study.

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