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Research Article

Application of Factor Analysis in Optimization of Scallop Meatball Formulation

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Abstract: In this study, bay scallop was used as primary material to produce scallop meatball. In order to determine the optimum formulation of scallop meatball, orthogonal test was conducted to investigate the effect of scallop content, corn starch content, soy protein isolate content on the sensory evaluation and texture properties through factor analysis, range analysis and variance analysis. Statistical analysis of the results showed that, in the trial-level range, the optimal condition were 35% scallop, 10% corn starch and 4% soy protein isolate. Under the optimal condition, the protein, fat, salt and ash content of scallop meatball was 12.09, 4.30, 0.65% and 3.25g/100g, respectively.

Keywords: Bay scallop, factor analysis, orthogonal, sensory evaluation, texture properties

INTRODUCTION

The bay scallop (*Argopecten irradians*) is one of the most important aquaculture scallops in China with the top economic value and the bay scallop had a production of 800, 000 ton in 2011 (Chen *et al*., 2015). The bay scallop is very famous for the delicious taste and abundant nutrition (Yi *et al*., 2013), such as protein, essential amino acid, unsaturated fatty acid (Lou *et al*., 2012), polysaccharide (Li *et al*., 2014a) and polypeptide (Zeng *et al*., 2004). In China, the main products of the bay scallop are limited to traditional processing method of dried and fresh frozen. Traditional scallop products have the limited scales radius and the low added value. The development and utilization of bay scallop is on the primary stage and the single form of the products can not satisfy the demand of the consumer (Li *et al*., 2009; Gao *et al*., 2011).

As an extension and deepening of principal component analysis, factor analysis is a multivariable analysis method that can attribute many complex variables to minority comprehensive factors (Liu, 2011). Thus, to evaluate the quality of scallop meatball comprehensively and avoid the deviation of the subjective weight, applying factor analysis to the combine subjective index with objective index organically. Factor analysis can attribute subjective and objective index into minority and uncorrelated new factors, which can include the most information of the original index and dimensionality reduction to interpret the correlation of the original index (He and Xu, 2003).

In order to develop products which not only meet the need of taste and nutrition but also enhance the added value of bay scallop is an important mission that promotes the stable and sustainable development of the bay scallop industry. For this purpose, we used bay scallop as primary material to develop a kind of scallop meatball and determine the scope of its optimum level through single-factor test. The optimum processing conditions were carried out with analysis the change in sensory evaluation and texture properties by orthogonal test and factor analysis. By this production technique, rich scallop flavor and good quality of meatball was had, added value of primary material was enhanced, a new way to develop and utilize scallop was provided.

MATERIALS AND METHODS

Materials: Bay scallop for this study purchased from the local market in Qinhuangdao, Hebei Province, China. Minced fish, fat pork, corn starch, salt, sugar, monosodium glutamate, pepper powder, soy protein isolate, compound phosphate, carrageenan, potassium sorbate were purchased from Wal-Mart supermarket.

Instruments: TMS-Pro texture analyzer was purchased from Food Technology Corporation. Meat grinder, stainless steel boiler and induction cooker were purchased from Joyoung limited company.

Preparation of scallop meatball: Scallop is the main ingredient in the production of the scallop meatball.

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Table 1: Sensory evaluation standard

Index	Standard	Score
Color	The color is dinginess without luster and the color show an uneven distribution	0
	The color is ivory-white with brightness and the color show an well distribution	15
Flavor	The scallop flavor is not prominent and coordinated, fishy smell or other undesirable smell.	0
	The scallop flavor is prominent and coordinate, no fishy smell or other undesirable smell.	30
Structure properties	The texture is roughness, have big and uneven distribution pores.	0
	The texture is compact, have small and even distribution pores.	20
Taste	The taste is not harmonious, the softness is poor, has excessively salty phenomenon and residues.	0
	The taste is harmonious, have both salty and fresh fragrance, no residues.	35

Table 2: Factors and levels of the test

Scallop content (%)	Salt content (%)	Sugar content (%)	Starch content (%)	Soy protein isolates content (%)
15	1	1	6	4
25	2	2	8	6
35	3	3	10	8
45	4	4	12	10
55	5	5	14	12

Fresh scallops and fat pork were cut up by meat grinder at 30 seconds respectively after being washed well. Then, other food ingredients such as minced fish, corn starch, salt, sugar, soy protein isolate content, 0.5% monosodium glutamate, 0.1% pepper powder, 0.3% compound phosphate, 0.6% carrageenan, 0.08% potassium sorbate were mixed together with minced scallop and fat pork (The weight of bay scallop and minced fish were seen as 100%). The batter was manufactured into 20g±1g meatball after being stirred 30 min. Finally, the meatball was cooked in water at temperature of 90-95°C for 5 min (Yasin *et al*., 2016).

Method of sensory evaluation: Sensory evaluation including color, flavor, structural state, taste were carried out by a thirty-member panel which have rich experience in the sensory testing of food (Li *et al*., 2014b), using a different points hedonic scale according to Table 1.

Method of textural analysis: Texture properties of scallop meatball were determined by TMS-Pro texture analyzer. Test parameters were as follows: velocity before test: 30 mm/min, test velocity: 120mm/min, velocity after test: 30 mm/min, sample deformation: 40%, probe head: FTC 38 mm diameter platen; Sample standard: cube with 25mm diameter. Test indexes include hardness, springiness, gumminess and chewiness (Lu *et al*., 2014).

Determination of physicochemical index in scallop meatball: The determination of protein, fat and ash referred to the national food safety standard. The determination of salt referred to the national Aquatic Products standard, determination of salt in aquatic products.

Single factor trial design: Combined with pre-experiment, the main factor affecting the quality of scallop meatball and the scope of this study were shown in Table 2. In every single factor, the other factor was fixed: 30% bay scallop, 1% salt, 1% sugar, 8% corn starch, 4% soy protein isolate content.

Orthogonal test design: Orthogonal test is the most commonly used in trial design method. On the basis of single-factor test, using F-value of factor analysis as an indicator, scallop content, corn starch content, soy protein isolate content as independent variables, to optimize the process condition of scallop meatball. Test levels of each factor were shown in Table 3.

Statistical analysis: The statistical study was performed using SPSS, version 19.0 for windows.

RESULTS AND DISCUSSION

Effects of scallop content on the sensory: Sensory evaluation results of meatball prepared by different scallop content were shown in Fig. 1. From Fig. 1 it could be found that when the scallop content was between 15~55%, the sensory scores increased and then decreased and the scores reached the highest when the scallop content was 35%. The content of scallop in the meatball had a significant impact on the sensory. Too much or little scallop in the meatball both caused lower scores. The reason may be that too little scallop is not conductive to the scallop flavor, while too much scallop is conductive to fishy smell or other undesirable smell. On the other hand, too little scallop is not conductive to the formation of the gel. And then, the hardness and springiness of meatball became smaller. The relationship between scallop content and sensory scores was parabola and the correlation coefficient of the curve fitting was $R^2 = 0.9834$.

Effects of salt content on the sensory: Sensory evaluation results of meatball prepared by different salt

Table 3: Result of orthogonal test program

	Factor				Texture properties			
Test number	Scallop	Starch	Soy protein isolate	Blank	Hardness X_5	Springiness X_6	Gumminess X_7	Chewiness X_8
1	30	8	4	1	6.280	4.90	4.350	21.34
2	30	10	6	2	8.110	6.10	5.960	36.41
3	30	12	8	3	11.58	5.92	9.750	57.71
4	35	8	6	2	15.10	6.40	10.83	69.68
5	35	10	8	3	18.40	5.80	12.96	75.70
6	35	12	4	1	13.10	6.00	11.01	66.32
7	40	8	8	3	20.30	6.10	15.00	87.60
8	40	10	4	1	21.70	5.40	15.60	84.82
9	40	12	6	2	23.41	7.08	19.43	137.52

	Sensory scores			
Test number	Color X_1	Flavor X_2	Structure properties X_3	Taste X_4
1	2	2	2	2
2	9	13	9	11
3	9	6	8	8
4	13	21	13	22
5	14	28	18	34
6	11	24	12	24
7	10	11	11	10
8	11	12	12	11
9	9	10	10	9

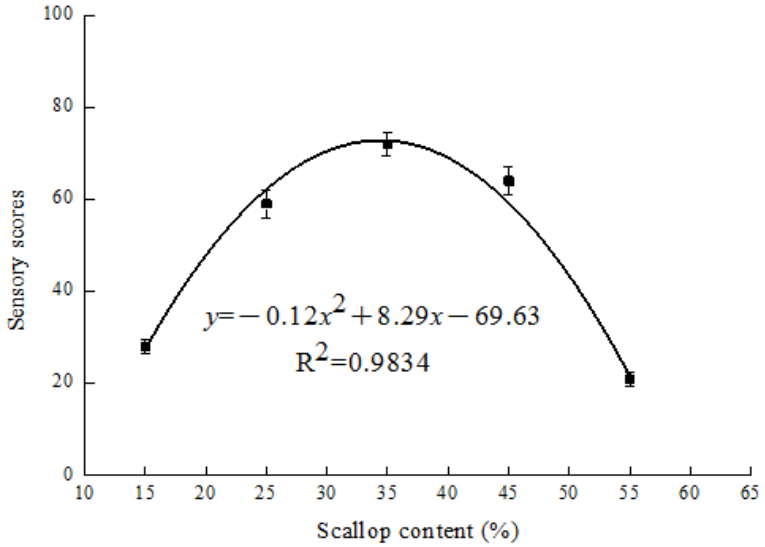

Fig. 1: Effect of scallop content on the sensory scores

content were shown in Fig. 2. From Fig. 2 it could be found that the sensory scores increased and then decreased as the salt content increased. The scores reached the highest when the salt content was 2%. The content of salt in the meatball has a significant impact on the sensory. With the increased of salt content, the dissolution of salt soluble protein increased. And then, the content of myosin elevated. The gel properties also increased with myosin content (Benjakul *et al*., 2003). However, considering the tolerance of salinity for people was 2~3% and the taste of scallop meatball, it is not appropriate to add too much salt. The relationship between salt content and sensory scores was parabola and the correlation coefficient of the curve fitting was $R^2 = 0.9704$.

Effects of sugar content on the sensory: Sensory evaluation results of meatball prepared by different sugar content were shown Fig. 3. From Fig. 3 it could be found that with the enhancement of the sugar content between 1~5%, the sensory scores increased between 1~2% and then decreased between 2~5%. The scores reached the highest when the sugar content was 2%. The content of sugar in the meatball has a significant impact on the sensory. Too much sugar in the meatball caused lower scores. The reason is probably that, with the increase of sugar content, the strong sweetness cover up other flavor. The relationship between sugar content and sensory scores was parabola and the correlation coefficient of the curve fitting was $R^2 = 0.9802$.

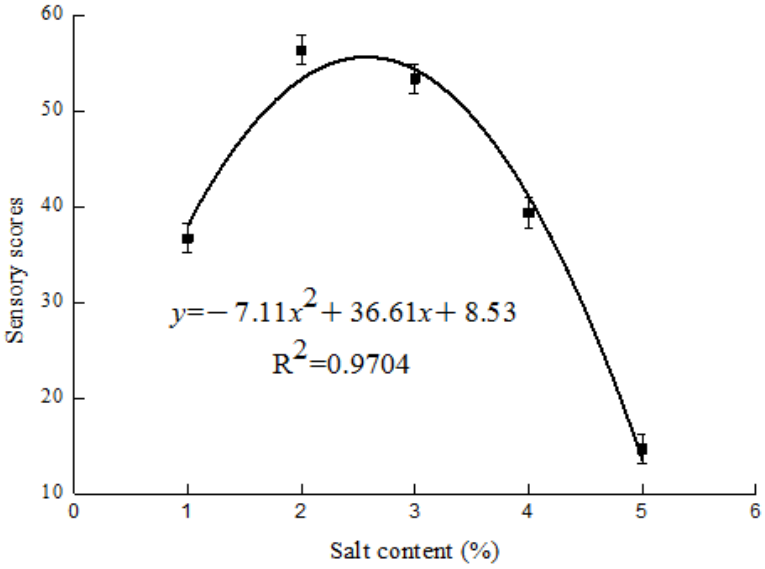

Fig. 2: Effect of salt content on the sensory scores

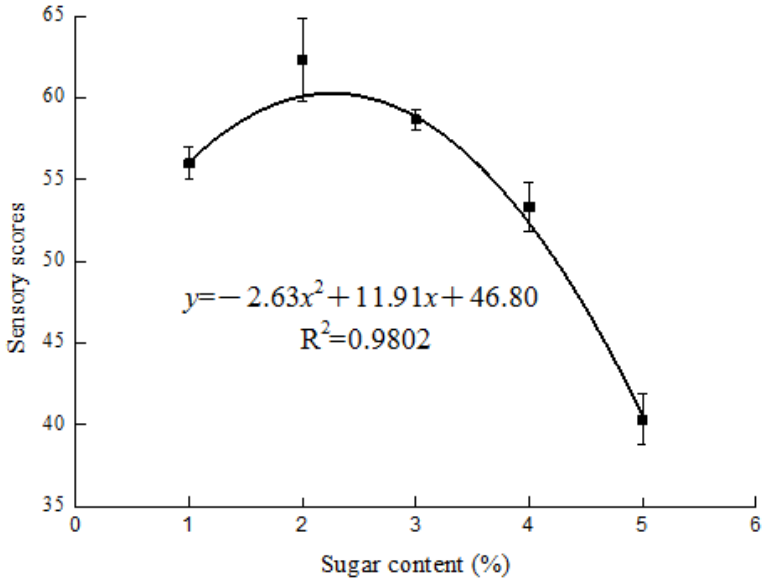

Fig. 3: Effect of sugar content on the sensory scores

Effects of corn starch content on the sensory: Sensory evaluation results of meatball prepared by different starch content were shown Fig. 4. From Fig. 4 it could be found that with the enhancement of the starch content, when the starch content was between 6~10%, the sensory scores increased; when the starch content was between 10~12%, the sensory scores decreased. The scores reached the highest when the starch content was 10%. The content of starch content in the meatball has a significant impact on the sensory. Adding starch can raise the water holding capacity of meatball and make the tissue of meatball fan. However, too much starch fades the taste and forms amounts of residues. The relationship between starch content and sensory scores was parabola and the correlation coefficient of the curve fitting was $R^2 = 0.9811$.

Effects of soy protein isolate content on the sensory: Sensory evaluation results of meatball prepared by different soy protein isolate content were shown Fig. 5. From Fig. 5 it could be found that with the enhancement of the soy protein isolate content, when the soy protein isolate content was between 4~12%, the sensory scores increased and then decreased. The scores reached the highest when the soy protein isolate content was 6%. The content of soy protein isolate content in the meatball has a significant impact on the sensory. Adding a certain amount of soy protein isolate can

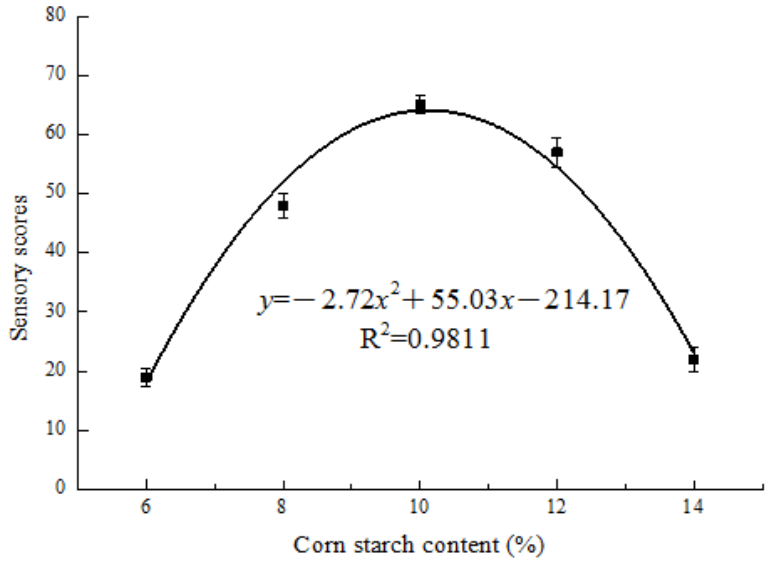

Fig. 4: Effect of corn starch content on the sensory scores

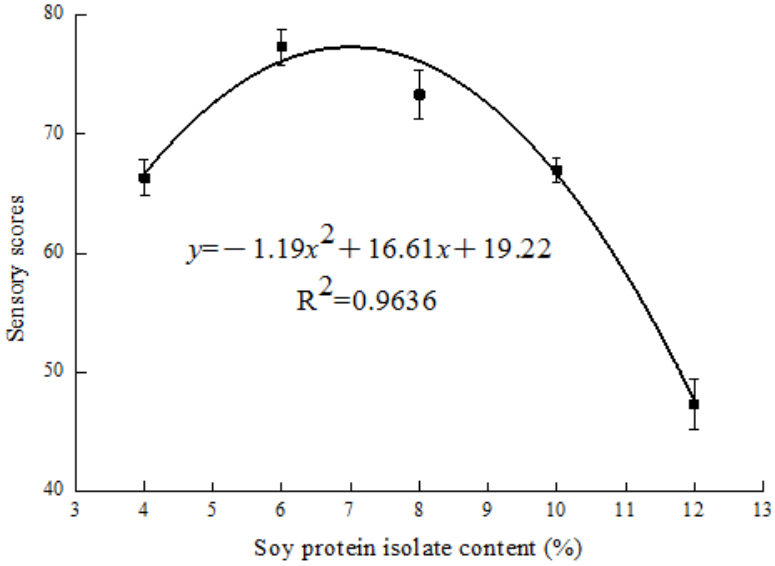

Fig. 5: Effect of soy protein isolate content on the sensory scores

increase water holding capacity, emulsibility and chewiness of meatball (Lu *et al*., 2014). Too much soy protein isolate in the meatball caused lower scores because of the increase of hardness and decrease of Springiness. The reason may be that, soy protein isolate promotes covalent cross-linking between protein molecules or polypeptide chains. The relationship between soy protein isolate content and sensory scores was parabola and the correlation coefficient of the curve fitting was $R^2 = 0.9636$.

Orthogonal test processing optimization result and analysis: On the basis of single factor test, the process condition of scallop meatball was optimized by the orthogonal experiment considering the effect of scallop content, soy protein isolate content, starch content. Test results were shown in Table 3.

Firstly, the KOM and Bartlett spherical test were carried out on the sensory scores and texture properties of the orthogonal experiment samples. The value of KOM ranges from 0~1. If the value of KOM<0.5, the experiment will not adjust for factor analysis. The statistical significance of Bartlett spherical test is checked by the p-value which checks correlated matrix is identity matrix or not. If the inspection results not refuse the hypothesis of the identity matrix (p>0.05), the experiment will not adjust for factor analysis (Liu, 2011). In our study, the inspection results were shown in Table 4. From Table 4 we can found that the value of KOM was 0.600 and the P-value of Bartlett spherical

Table 4: Inspect of KOM and Bartlett

Kaiser-Meyer-Olkin measurement of sufficient sampling degree		0.600
Bartlett spherical test	Approximate Chi-square	88.545
	df	28.000
	Sig.	0.0000

Table 5: Characteristic value and contribution rate

Factors	Characteristic value	Contribution rate/%	Cumulative contribution rate/%
F1	4.93	61.66	61.66
F2	2.24	28.04	89.70

Table 6: The coefficient matrix of component score

	Factors
Indexes	F1	F2
Hardness	-0.041	0.274
Springiness	-0.030	0.210
Gumminess	-0.069	0.297
Chewiness	-0.087	0.309
Color	0.233	0.022
Flavor	0.308	-0.099
Structure properties	0.244	0.017
Taste	0.314	-0.113

Table 7: Result of range analysis

	Factor				Factor scores		
Test number	Scallop	Starch	Soy Protein Isolate	Blank	F1	F2	F
1	30	8	4	1	-0.36	10.29	2.660
2	30	10	6	2	7.660	14.34	8.740
3	30	12	8	3	2.060	23.98	7.990
4	35	8	6	2	11.96	26.17	14.71
5	35	10	8	3	18.55	27.50	19.14
6	35	12	4	1	13.17	23.97	14.84
7	40	8	8	3	1.870	36.55	11.39
8	40	10	4	1	3.130	35.94	12.00
9	40	12	6	2	-4.03	54.53	12.78
k1	6.4630	9.5870	9.8330	11.527			
k2	16.230	13.293	12.077	11.657			
k3	12.057	11.870	12.840	11.567			
R	9.7670	3.7060	13.007	0.1300			

Table 8: Results of ANOVA

Item	Quadratic sum (III)	df	Mean square	F	Sig.
Model	179.724[a]	6	29.954	2252.180	0.000
Scallop content	144.090	2	72.045	5416.912	0.000
Starch content	20.9790	2	10.489	788.6790	0.001
soy protein isolate	14.6550	2	7.3280	550.9500	0.002
Error	0.02700	2	0.0130		
Total	179.751	8			

test closed to 0, refused primary hypothesis of the identity matrix. Thus, this study adjusted for factor analysis.

Extracting factors according to the principle of cumulative proportion and characteristic value of factors >1. As Table 5 shown, after the treatment of factor analysis, 8 independent variables can attribute to 2 main factors, which obtained 89.70% original information. The weight of F_1 was 61.66 and the weight of F_2 was 28.04. According to the coefficient matrix of main factors showed in Table 6, the scores of each sample were:

$$F_1 = -0.041X_1-0.030X_2-0.069\ X_3-0.087\ X_4+0.233\ X_5+0.308\ X_6+0.244\ X_7+0.314\ X_8$$

$$F2 = 0.274X_1+0.210X_2+0.297X_3+0.309X_4+0.022X_5-0.099\ X_6+0.017\ X_7-0.113\ X_8$$

The model of scallop meatball quality evaluation was: $F = 0.6166\ F_1+0.2804F_2$

To calculate the comprehensive scores (F-value) of orthogonal experiment samples according to the model of scallop meatball quality evaluation and analyze the range. The results were shown in Table 7. Based on the Range (R), the importance of independent variables on comprehensive scores (F-value) could be ranked in the following order: soy protein isolate >corn starch> scallop. The range of the blank was minimum, indicating the test was not missing any important factors. Trial optimal solution was program $A_2B_2C_3$, namely the scallop content was 35%, corn starch

content was 10% and soy protein isolate content was 4%.

Analysis of variance (ANOVA) can be used to examine the significance of the relevant factors on the test results (Lin *et al*., 2015). Analysis of variance results were shown in Table 8. As it can be seen from Table 8, the test model was extremely significance. The influence of scallop, corn starch and soy protein isolate content were both extremely significance.

Verification test: The repeat experiments were conducted under optimal condition for verification of the optimization. Combined with the actual production, there might be slight variation in experimental conditions. The color, flavor, structure properties and taste of the scallop meatball sensory scores were 13± 1.12, 29±2.67, 30±1.04 and 35±2.21. The hardness, springiness, gumminess and chewiness of scallop meatball were 15.9±0.12N, 6.03±0.45mm, 12.94±1.06N and 78.00±13.90mJ. These values were found to be in agreement with the predicted value. Under the optimal condition, the protein, fat, salt and ash content of scallop meatball was 12.00, 4.30, 0.65% and 3.25 g/100g, respectively.

CONCLUSION

This study showed that using scallop as primary material to produce unique seafood flavor meatball is feasible. On the basis of single factor test, adding 2% salt and 2% sugar was suitable according to the sensory evaluation. We conducted optimization study on the content of scallop, corn starch and soy protein isolate through orthogonal trial and factor analysis, range analysis and variance analysis. Results showed that, in the trial level range, scallop content, starch content and soy protein isolate content both had significance effect on the quality of scallop meatball. Moreover, the optimal condition was as follows: scallop content was 35%; starch content was 10%, soy protein isolate content was 4%. Under the optimal processing condition, the protein, fat, salt and ash content of scallop meatball was 12.09, 4.30, 0.65% and 3.25g/100g, respectively.

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