

Effect of Soy Protein Isolate on Quality of Fried Breaded Shrimp

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Abstract: Higher oil content in fried food shortens the shelf life of the product and causes a decrease of product acceptability to consumers. The fat content absorbed by fried food can be reduced by using appropriate coatings such as flour or batter. In this paper, the effects of soy protein isolate (SPI) addition to the wheat flour-based batter on the quality of fried breaded shrimp were evaluated. The coating powder rate, moisture loss, oil absorption, color, texture and sensory attributes of the samples were determined. Breaded shrimps were fried at 175 °C for 3 min. The results showed that SPI significantly increased the coating rate of the fried breaded shrimps ($p < 0.05$), meanwhile decreased moisture loss and oil content. When the content of SPI increased from 2 g to 10 g, the amount of moisture loss and oil absorption in the fried breaded shrimps decreased from 15.12% to 11.64%, and 25.07% to 19.82%, respectively. In addition, adding 8 g SPI to the batter provided the best texture property and the highest sensory score. However, there was no significant difference for the variation of L^* , a^* and b^* value with respect to different concentrations of SPI added to the batter formulation.

Key words: soy protein isolate; breaded shrimp; frying; physical properties

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添加大豆分离蛋白对油炸面包虾品质的影响

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摘要: 油炸产品通常脂肪含量较高, 这会缩短产品的货架期, 同时会使得消费者对产品接受度的降低。然而, 在油炸过程中, 油炸产品的吸油量可以通过裹粉或者裹浆而降低。该研究拟在以小麦粉为主体的裹浆粉中添加大豆分离蛋白, 以面包虾的裹粉率、水分损失量、吸油量、色泽、质构以及感官评定等为指标, 研究添加大豆分离蛋白对油炸面包虾品质的影响。油炸条件为 170 °C, 油炸 3 min。结果表明, 大豆分离蛋白显著增加面包虾的裹粉率, 且发现它能有效降低油炸面包虾产品的水分损失和吸油量。当大豆分离蛋白的添加量从 2 g 增大到 10 g 时, 油炸面包虾的水分损失和吸油量分别从 15.12% 和 25.07% 降低到 11.64% 和 19.82%。此外, 在裹浆中添加 8% 大豆分离蛋白的面包虾具有最好的质构特性且获得较高的综合感官评分。然而, 添加大豆分离蛋白到裹浆中并不会对油炸面包虾的亮度、黄度及红度产生极显著的影响。

关键词: 大豆分离蛋白; 面包虾; 油炸; 物理特性

Consumption of battered and breaded foods especially seafood, poultry, cheese and vegetables has become very popular within the last few years^[1]. Breaded shrimp is one of the most widely consumed shrimp products especially in developed countries due to

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its high nutritious value, attractive appearance, unique flavor and convenient consumption. At present, frying is the main cooking style of breaded shrimp.

Frying significantly reduces shelf life of food products. This quick and easy preparation process results in products with organoleptic quality (color, texture, and flavor) much in demand by appreciative consumers^[2]. However, fried foods contain a significant fat content, reaching 1/3 of the total weight of the product in some cases^[3], which has become a health problem associated with obesity and coronary heart disease^[4]. In recent years, consumer's preference for low-fat and fat-free products

has led to the need to produce lower oil content products that still retain the desirable texture and flavor^[5,6].

The crusts of breaded shrimp often contain three parts: pre-dusts, batters, and breadcrumbs. The batters play a key role in the crusts, in which the ingredients of batter affect its characteristics^[7], thereby determining all the final quality performance of the coated foods. Wheat flour is the most common flour used in batter systems, due to its considerable amount of proteins that necessary to form elasto-plastic batter^[8]. In addition, rice and soy flour, starch, hydrocolloids, alginate, cellulose and its derivatives, soy protein isolate, whey protein, albumin, gluten and leavening agent are also the important batter ingredients^[3, 5, 9-12]. So far, many studies have reported that adding soy flour, rice flour, corn flour, hydrocolloids and so on into the batters not only reduced the oil absorption, but also improved the quality of fried products^[1, 4, 8, 13, 14].

SPI is an abundant, inexpensive, biodegradable, and nutritional raw material^[15]. As one of protein, SPI has very important functional properties such as gelation, thickening, emulsification, foaming and elasticity, and provides essential amino acids; therefore it could fulfill functional and nutritional requirements. Furthermore, batter formulations containing SPI have been reported to result in slightly lower oil absorption^[10, 16]. However, few studies are available in literatures about its effects on fried food. The main objective of this paper was to study the effect of SPI addition on the coating powder rate and the quality properties of fried breaded shrimp.

1 MATERIALS AND METHODS

1.1 Materials

Shrimps (*Litopenaeus vannamei*) with the average size of 52~56 shrimps/kg were purchased from the local seafood wholesale market in Zhanjiang, Guangdong. The shrimps were covered with ice cube immediately and transported to the laboratory rapidly. Upon arrival, shrimps were washed in ice water and kept frozen (at -20 °C) prior to use.

Wheat flour (Moisture 13.86%, Protein 12.09%, Crude fat 0.92%, Ash 0.09%), sugar, salt and soybean oil were purchased from Wal-Mart supermarket (Zhanjiang, China). Sodium tripolyphosphate, soy protein isolate (Moisture 7.73%, Protein 91.06%, Crude fat 0.40%, Ash

0.10%) were purchased from Chenyang chemical industry Co., Ltd (Zhengzhou, China). Pre-dust and breadcrumbs were purchased from Niuliwei Food Co., Ltd. (Beijing, China).

1.2 Batter preparation

The batter formulation was shown in Table 1. The thoroughly pre-blended powders were mixed with purified water (1:1.80, *m/m*) and stirring (Hankang Co., Ltd, Shanghai, China) for 5min to ensure uniform mixing.

Table 1 Ingredients and compositions in batter flours (g)

Formulation	Wheat flour	SPI	Sugar	Salt
W	100	0	10	5
2WS	98	2	10	5
5WS	95	5	10	5
8WS	92	8	10	5
10WS	90	10	10	5

1.3 Sample preparation and frying

Frozen shrimps were defrosted in a refrigerator at 4 °C over night. The thawed samples were beheaded, peeled, deveined, and the tails were kept. The abdominal segments of the shrimps were excised with a knife from the back to tails and made depth of slits account for about 90% of the abdominal segments. Then the shrimps were washed with ice water. Shrimps were then soaked in a saline solution for 40 min, which consisted of salt and sodium tripolyphosphate of 1.50 g/L, rinsed with cold water and placed on a stainless steel screen for 5 min to remove the excess moisture from the surface of shrimps. Each sample was weighed before coating and found to have a uniform range of 12.00 ±2.01 g. In the first step, shaped samples were coated by the pre-dusts. In the subsequent step, the samples were immersed individually into a beaker which contained the batter suspension for 30 s and then allowed to drip for 15 s. Finally, they were breaded with breadcrumbs and weighed again to determine the coating mass. The coated shrimps (breaded shrimps) were stored in a refrigerator at -18 °C for 24 h.

Before frying, frozen breaded shrimps were removed from the refrigerator and thawed in the room temperature for 2 min. The samples were fried at 175 °C in frying pan (Cuibai Co., Ltd, Beijing, China) containing 1 L soybean oil. A temperature measuring instrument (testo AG, Germany) was used to measure the

temperature of oil during frying. Three samples were fried each time. The samples were placed in a fryer basket to keep them submerged for 3 min. The frying oil was replaced with fresh oil after 1h frying. After the frying time, the fryer basket was immediately lifted out from oil and left to stand for 2 min. Then the samples were removed from the fryer and cooled to room temperature before analysis. The sequence of steps in the complete process is presented in Fig.1.

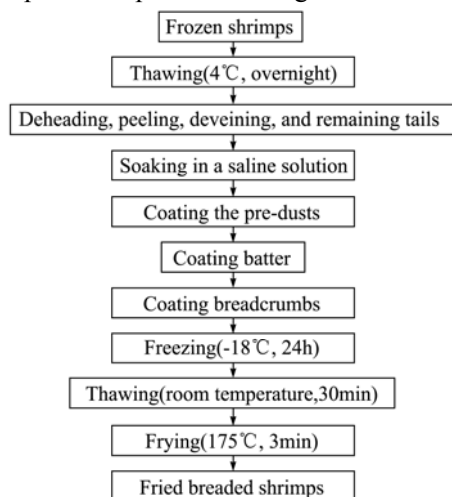


Fig.1 Flow diagram of the process of making fried breaded shrimps

1.4 Test method

1.4.1 Coating powder rate

Coating powder rate is generally used to denote the amount of coating material adhering to the samples during coating prior to frying. The coating powder rate of the final product is defined as:

$$\text{Coating rate}(\%) = \left(\frac{C}{C+S} \right) \quad (1)$$

Note: Where C is the mass of the coating materials adhering to the shrimp after coating and S is the mass of the shrimp before coating. Three replications were carried out.

1.4.2 Moisture content determination

Moisture content determination was carried out using the method from Andres-Bello et al^[17] with some modifications. The whole fried samples were first grounded with a blender (PHILIPS, Netherlands), then weighed and dried in an oven (Yiheng Co., Ltd, Shanghai, China) at 105 °C for 24 h. The dried samples were cooled in desiccators and moisture content was obtained in terms of percentage. Moisture loss was calculated using the difference between the original moisture content and the moisture content at time t.

1.4.3 Fat content determination

The fat content of fried samples was determined using the method described by Nasiri et al^[14] with some modifications. The dried samples (2~4 g) used for moisture content determination were subsequently weighed, packaged in a filter paper and placed in a bushing. Fat was extracted in solvent extractor using petroleum ether (Analytically pure, CAS64742-49-0) for 10 h. The extracted fat was further dried at 105 °C for 3 h to remove residue solvent and moisture. Then the fat was cooled in desiccators and subsequently weighed. The fat content was obtained in terms of percentage. And oil absorption was calculated using the difference between the original fat content and the fat content at time t.

1.4.4 Color analysis of fried breaded shrimps

The color of fried breaded shrimps was determined using a colorimeter (Konica Minolta Investment Ltd, Beijing, China) based on the CIELAB color parameters, L*, a*, and b*. A standard white calibration plate was employed to calibrate the equipment. The colorimeter parameters were a D65 light source, 10° standard observer and a 30 mm diameter measuring area. Three replications were used. The total color difference (ΔE) was calculated from Eq. 2:

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (2)$$

Note: Where ΔL , Δa , and Δb were the difference between the control samples and the treatment groups with reference to L*, a*, and b* values, respectively.

1.4.5 Texture analysis of fried breaded shrimps

The crusts were removed from the breaded shrimps, and prepared in slab shapes of 1.50, 1.50, 0.20 cm using a manually operated cutting device and the maximum breaking force or hardness of crusts was measured using a Texture analyzer (Food Technology Corporation, Virginia, USA) with a 1000 N load cell. Samples were punctured with a cylindrical probe (5 mm diameter) and the crosshead speed was set to 60 mm/min. The highest peak on the force-time curve was assumed as a hardness value. Each analysis was conducted using 10 samples.

1.4.6 Sensory evaluation

Sensory analysis of the fried breaded shrimps was conducted immediately after cooling to room temperature. Evaluations were made by 40 trained panelists. The panel was trained to recognize and score the quality attributes

of the fried breaded shrimps. Five sensory attributes were evaluated (color, texture, taste, flavor and overall acceptability) using a 5-point scale for each trait, where five of them represented very well and one represented bad. Randomly coded samples were served to assessors individually. Spring water was provided between samples for mouth rinsing by each assessor.

1.4.7 Statistical analysis

All measurements were done in at least three replications. The software JMP (Version 7, SAS Institute Inc., Cary, North Carolina, USA) was utilized to calculate analysis of variance (ANOVA). Duncan's multiple range tests were applied to determine the significant differences between treatments at the 95% confidence interval.

2 RESULTS AND DISCUSSION

2.1 Rate of coating materials

Coating powder rate is an important index in the coated products. In general, coating power rate is between 30~50%. It is directly correlated with batter viscosity, that is, as viscosity increases, more coating material remains on the sample^[1,18].

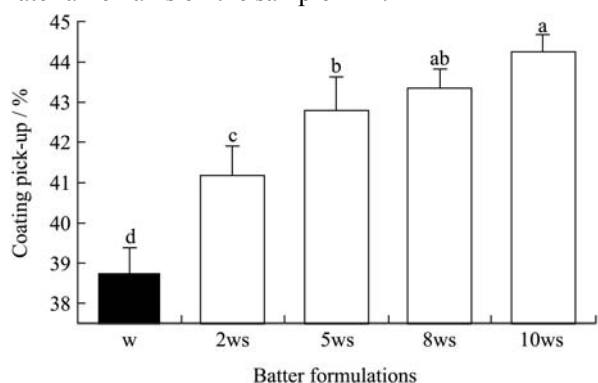


Fig.2 Effect of different batter formulations on coating powder rate of breaded shrimps

Note: w 100 g wheat, 2ws 98 g wheat and 2 g SPI, 5ws 95 g wheat and 5 g SPI, 8ws 92 g wheat and 8 g SPI, 10ws 90 g wheat and 10 g SPI. Error bar shows standard deviation. Values with different letters are significantly different ($p < 0.05$).

Coating powder rate for the different batter formulations were shown in Fig.2. Compared to the control batter which contains 100 g wheat flour, SPI addition increased coating powder rate of breaded shrimps significantly ($p < 0.05$). In addition, the coating powder rate of breaded shrimps increased with SPI concentration increasing. And the highest rate was found in samples contained 10 g SPI. This might be attributed

to its higher apparent viscosity. It is reported that the crusts produced by protein materials possessed better adhesion than other kinds of materials, such as starch or gums^[11]. SPI studied in this paper contained 91.25% protein, so it exhibited the strong adhesion in the batter and had significantly higher coating powder rate than the control batter. Nasiri et al^[14] reported that the coating powder rate of the shrimp nuggets was 56.30% when 10 g soy flour (about 47.05% protein) added to the batter, which was higher than the rate (44.25%) of breaded shrimps contained 10g SPI in this study. The fact could be due to the differences in water/dry mix proportion used in the batters and the coating methods. The water/dry mix proportion used in the batters for the former and latter were 1.2:1 (*m/m*) and 1.8:1 (*m/m*), respectively.

2.2 Moisture loss of fried breaded shrimps

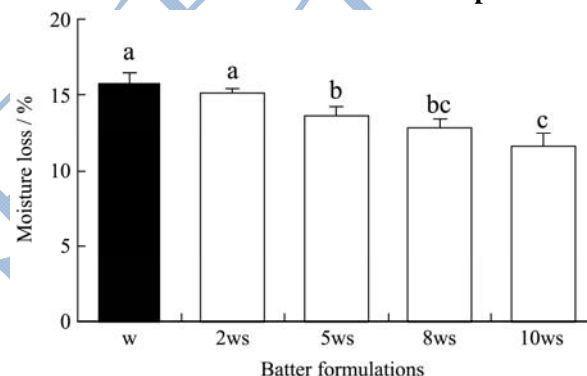


Fig.3 Effect of different batter formulations on moisture loss of deep fried breaded shrimps

Note: w 100 g wheat, 2ws 98 g wheat and 2 g SPI, 5ws 95 g wheat and 5 g SPI, 8ws 92 g wheat and 8 g SPI, 10ws 90 g wheat and 10 g SPI. Error bar shows standard deviation. Values with different letters are significantly different ($p < 0.05$).

Fig.3 showed the effects of different batter formulations on the moisture loss of fried breaded shrimps. There were significant differences ($p < 0.05$) in the moisture loss among the fried breaded shrimps coated with the different batter formulations. In general, SPI addition significantly decreased ($p < 0.05$) moisture loss during frying. As concentration of SPI increased, the moisture loss for the same frying time decreased.

During frying, the temperature of oil is far above the boiling point of water, and the high temperature causes partial evaporation of the water, which moves away from the food and through the surrounding oil^[19]. Coatings covered on the surface of food products form the crusts during frying. The crusts of fried products can act as a

barrier against the moisture loss by protecting the natural juices of foods^[20]. Due to higher water binding capacity of protein, coating materials containing abundant proteins generally represent water-retention capacity^[1]. So, the result that SPI effectively decreased moisture loss during frying might be due to its higher water binding capacity. These results were in agreement with those obtained by Dogan et al^[20].

2.3 Oil absorption of fried breaded shrimps

The oil absorption is an important phenomenon in the area of frying which has been studied by many researchers. There are several factors that strongly affect oil absorption in fried products. Some of the most important are as follows: process conditions (temperature, time), pretreatment (blanching, drying and coating), oil quality and composition, product shape, initial moisture content of food ingredients, initial porosity^[21-24]. Moisture content is an important factor in determining oil absorption during frying. During frying, when moisture evaporation increases, more pores are generated in the food matrix^[8]. These capillary pores act as pathways in the food and subsequently filled by oil^[25]. There was an opposite relationship between moisture loss and oil absorption, so greater oil absorption is attributable to lower moisture retention in the frying process^[25,26].

There were significant differences ($p < 0.05$) in the oil absorption among the fried bread shrimps coated with the different concentrations of SPI (Fig.4). The addition of SPI to the batter formulation reduced oil absorption significantly during frying when compared with the control. As concentration of SPI increased, the oil absorption decreased. Fig.4 showed that the amount of oil absorption was only 20.10% when adding 8 g SPI in the batter formulation. This might be due to its higher protein content, higher water-binding capacity and higher viscosity, so it could control moisture loss and oil uptake during frying. Similarly, Dogan et al^[20] reported that the performance of SPI reduced fat uptake of fried chicken nuggets.

However, when the content of SPI continued to increase to 10 g, the amount of oil absorption was 19.82%, which was higher than the result (about 8.21%) obtained by Nasiri et al^[14] with adding 10 g soy flour to the batter. The fact might be the difference in coating methods. In this study, the crusts of breaded shrimp

contained three parts (the pre-dusts, batters and breadcrumbs). The excess oil content in the breaded shrimps might be attributed to the breadcrumbs. Compared to addition of 8 g SPI, the amount of oil absorption only reduced 1.49%, indicating the effect of SPI on oil absorption reduction was very weak when 10 g SPI was added. Due to higher viscosity of batter formulation, breaded shrimps would intake more oil from the oil bath.

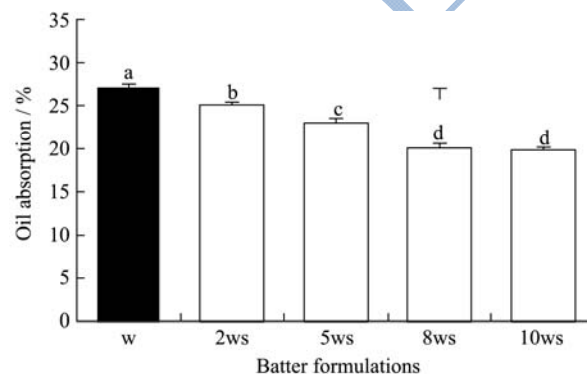


Fig.4 Effect of different batter formulations on oil absorption of deep fat-fried breaded shrimps

Note: w 100 g wheat, 2ws 98 g wheat and 2 g SPI, 5ws 95 g wheat and 5 g SPI, 8ws 92 g wheat and 8 g SPI, 10ws 90 g wheat and 10 g SPI. Error bar shows standard deviation. Values with different letters are significantly different ($p < 0.05$).

2.4 Texture of fried breaded shrimps

Textural quality is an important attribute for the acceptability of fries and it is influenced by both raw material and process conditions^[27]. Crunchiness is one of the most important and desirable textural characteristics of fried and coated products^[28]. The breaking force or hardness is an indicator of crunchiness. The effect of SPI at different concentrations on the texture of deep fried breaded shrimps was examined in terms of breaking force (Fig.5). Fried breaded shrimps included SPI in the batter formulation showed a lower breaking force than the control. This indicated that the addition of SPI to the batter formulation improved the crunchiness of fried breaded shrimps. Similarly, Chen et al^[29] reported that the crispness of fried crusts containing soy protein were higher than that of control.

It is reported that SPI has an excellent film-forming ability^[30]. The effect of SPI on the crunchiness of fried breaded shrimps also might be attributed to its film-forming property. The film-forming property was corresponded with the concentration of SPI. When its

content was below 5 g, SPI films were not fully formed, and only produced some small fragments. However, when the content of SPI exceeded 8 g, SPI films formed in the batter contained mass undissolved blob. As shown in Fig.5, the lowest breaking force was displayed when 8 g SPI was added in the batter formulation which might be due to its excellent SPI films.

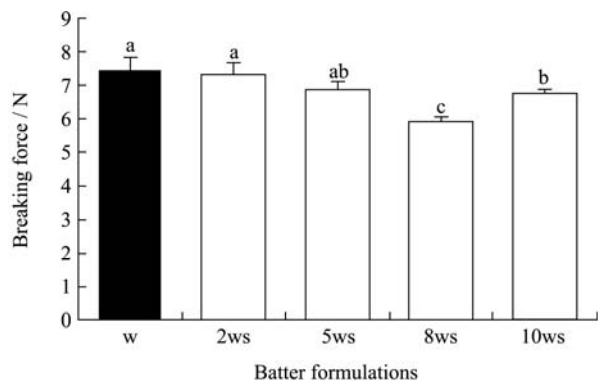


Fig.5 Effect of different batter formulations on texture of deep fried breaded shrimps

Note: w 100 g wheat, 2ws 98 g wheat and 2 g SPI, 5ws 95 g wheat and 5 g SPI, 8ws 92 g wheat and 8 g SPI, 10ws 90 g wheat and 10 g SPI. Error bar shows standard deviation. Values with different letters are significantly different ($p < 0.05$).

2.5 Color of fried breaded shrimps

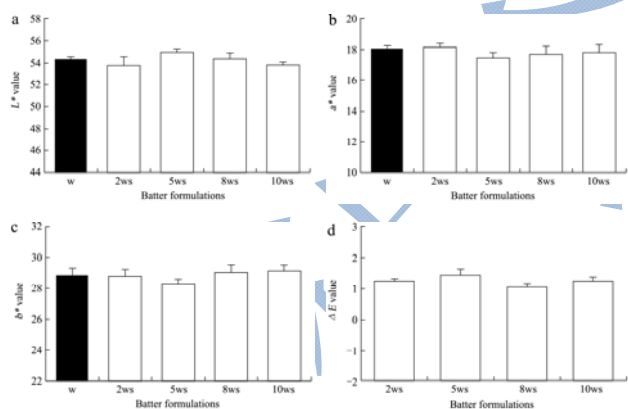


Fig.6 Effect of different batter formulations on (a) L*; (b) a*; (c) b*; and (d) ΔE color values of deepfried breaded shrimps

Note: w 100 g wheat, 2ws 98 g wheat and 2 g SPI, 5ws 95 g wheat and 5 g SPI, 8ws 92 g wheat and 8 g SPI, 10ws 90 g wheat and 10 g SPI. Error bar shows standard deviation

In general, color provides a useful measurement for determining changes due to processing condition and possible acceptability by consumers. The golden color of fried crusts appeared because of Maillard reaction and caramelization of sugars by frying treatment [28]. The influence of the different batter formulations studied on the parameter values for luminosity or clarity (L*),

green-red component (a *), and blue-yellow component (b *) obtained after final frying which were presented in Fig.6. There was no significant trend for the variation of L*, a* and b* value with respect to different concentrations of SPI added to the batter formulation. In the present work, the ΔE values for the color of fried breaded shrimps were also observed, but no differences were found. These results were different with those obtained by Dogan et al [20], which might be due to the difference between coating technologies.

2.6 Sensory evaluation of fried breaded shrimps

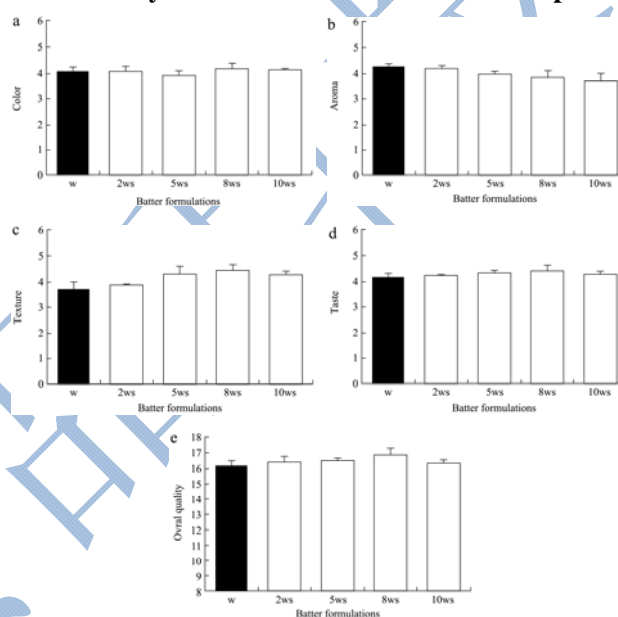


Fig.7 Effect of batter formulations on sensory attributes (a) color;(b) aroma;(c) texture;(d) taste and (e) overall quality of breaded shrimps

Note: w 100 g wheat, 2ws 98 g wheat and 2 g SPI, 5ws 95 g wheat and 5 g SPI, 8ws 92 g wheat and 8 g SPI, 10ws 90 g wheat and 10 g SPI. Error bar shows standard deviation.

Sensory scores of fried breaded shrimps coated with different batter formulations were showed in Fig.7. The addition of SPI to the batter formulation decreased aroma values of fried breaded shrimps when compared with the control. This might be attributed to the inherent beany flavor of SPI. For the texture value, the highest score of fried breaded shrimps was reported when 8 g SPI was added in the batter formulation, which was in agreement with instrument test results. The color, taste and overall acceptability in the sensory evaluation showed no significant differences for all samples. As far as the overall acceptability was concerned, maximum score was observed in fried samples containing 8 g SPI, which

illustrated that the fried breaded shrimps added 8 g SPI were attractive to the consumers.

3 CONCLUSION

3.1 According to the results, addition of different concentrations of SPI to the batter formulations was examined during frying of breaded shrimps. The results demonstrated that SPI added batters significantly ($p < 0.05$) increased the coating powder rate of breaded shrimp, reduced moisture loss and oil absorption of fried breaded shrimps, and improved brittleness of final product. The results of sensory evaluation indicated that fried breaded shrimps coated with batters containing 8 g SPI maintained the best texture property with lower oil absorption, representing a healthier snack for consumers, and were welcomed by sensory panel.

3.2 In order to produce wonderful fried breaded shrimps with lower oil absorption and highest quality properties, optimization of frying condition is recommended as a subsequent study.

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