EFFECTS OF SOUS VIDE COOKING ON PHYSICOCHEMICAL PROPERTIES OF SQUID

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Abstract

Sous vide refers to a cooking method, in which food is placed in a vacuum bag and cooked under a strictly controlled temperature and time condition. Sous vide differs from the traditional cooking in various aspects. The precisely controlled temperature and time not only reduce negative effect of cooking on nutrients (e.g., proteins, lipids, vitamins, etc.), but also increase total phenolic content and antioxidant activity and improve the overall texture and color of foods. Many experts and scholars have been working on sous vide-related research, which involves various research interests, such as: food safety, storage time, quality improvement, effects on nutrients, nutritional bioavailability, and various other technical approaches. Thus, this research was aimed to study the effect of sous-vide cooking of squid at different temperature combinations on different color, textural, pH and cooking loss.

In order to explore the changes of squid and physicochemical properties during sous vide cooking, the squid was vacuum treated and treated in water bath at: 55, 60, 65, 70, 75, 80, and 85 °C. The texture characteristics, color, pH, and cooking loss of each of the sous vide samples were measured and analyzed by heating at a constant temperature for 300 minutes. Texture was measured when the samples were cut into cubes of 2 x 2 x 2 cm by TA.XT Express material analyzer. The fish meat was determined by physical analyzer. Measuring conditions were as follows: SMS P/50 probe, 2 mm/s pre-test speed, 2 mm/s test speed, 10 mm/s post-test speed. The ambient temperature was 20-25 °C and was measured three times in parallel. Color was measured by using CR-400 chromatograph, and the L*, a* and b* values of samples were determined after white board calibration. Different cross sections of each sample were selected for three times. pH was measured by pH meter as follows: 10 g of sample was cut it into pieces, 90 mL of distilled water with pH of 7.0 was added, sample was soaked for 30 minutes and stirred continuously, and then tested with pH meter. Number of samples determined is not less than 3. Cooking losses were calculated by difference of weight before and after cooking and moisture content was determined by drying the samples (5 g) at 102 °C. All the control and treatment groups were repeated three times. Gained data were analyzed by SPSS 19.

The results showed that the quality of squid with sous vide cooking was significantly improved. With the increase of cooking heating temperature, the pH, hardness, elasticity, and chewiness of squid increased first and then decreased. The squid under 60 °C heating condition had better texture characteristics. Sous vide cooking had a significant effect on the color and cooking loss of the squid (p < 0.05), and the squid had the least cooking loss under heating at 55 °C.

In conclusion, the increase in heating temperature has a significant effect on the texture, color, pH, cooking loss, etc. of sous vide cooking (p < 0.05) Combining good changes in texture and cooking loss commendable 60 °C as a superior sous vide cooking environment.

Key words: Squid, Sous vide cooking, Physicochemical property, Texture.
1. Introduction
Argentinian squid (*Illex argentinus* Castellanos), belongs to the phylum *Mollusca*, class *Cephalopoda*, order *Oegopida* squid branch *Ommastrephidae* Steenstrup, genus *Illex* [1]. It is an oceanic shallow sea species with short life span and rapid growth [1]. The squid is rich in nutrients, high in protein and low in fat, rich in essential amino acids, and essential amino acid composition is close to whole egg protein, which is a nutritious and health-care type, and also have a good flavor of aquatic product. Invertebrates such as squid and common fish have different proteins. In addition to sarcoplasmic proteins, myofibrillar proteins, and muscle matrix proteins, they also contain partial paramyosin [2], which is a protein unique to invertebrates. The proteins of invertebrates such as squid exhibit some special properties different from ordinary fish meat proteins.

After the meat is heated, a series of physical and chemical changes will occur, which will greatly affect the quality of the processing, such as volume changes caused by muscle contraction [3], loss of quality caused by juice loss [4], nutrient loss [5, 6], color change [7, 8], changes in texture (such as hardness, tenderness, shear force, elasticity, etc.), and other changes [9-11]. All of these changes are not independent.

Sous vide refers to a cooking method, in which food is placed in a vacuum bag and cooked under a strictly controlled temperature and time condition [12]. Sous vide differs from traditional cooking in various aspects. The precisely controlled temperature and time not only reduce the negative effect of cooking on nutrients (e.g., proteins, lipids, vitamins, etc.), but also increase total phenolic content and antioxidant activity and improve the overall texture and color of foods. Many experts and scholars have been working on sous vide-related research, which involves various research interests, such as: food safety [13], storage time [14], quality improvement [15], effects on nutrients [16], nutritional bioavailability [17], and various other technical approaches [18].

Sous vide has different effects on the texture, color, flavor and taste of animal products. In the case of aquatic products, steam cooking at 70 °C for 60 min. can obtain low-temperature vacuum cooking sea cucumber with moderate hardness, crispy taste, certain elasticity and chewiness [19]; scallops need to be cooked at 65 °C for 20 min. to obtain better taste. If cooking temperature is too high, and time is too long, the scallops taste worse [20]. Cooking at 90 °C for 15 min. will cause low-temperature vacuum cooking of squid slices due to protein agglomeration leading to poor meat color and protein precipitation [21]. Unlike aquatic products, low-temperature vacuum cooking of livestock and poultry meat requires relatively high temperatures and longer cooking times [22]. The cooking loss of lamb cooked under vacuum at 70 °C and 80 °C is higher than cooking at 60 °C. The cooking at 60 °C has higher brightness value (L*) and redness value (a*) than at 70 °C and 80 °C. Increasing the cooking time increases the yellowness of the lamb (b*) [23]. Li, [24], found that when the beef was heated at 70 - 90 °C, the connective tissue of the muscle bundle and endomysium was granulated without gelation, which may be related to the shorter heating time (less than 30 min.). Temperature has a significant effect on the color and texture of low-temperature vacuum cooking pork products. L*, a*, b*, hardness, elasticity and chewiness all decrease with increasing temperature [25].

Thus, this research was aimed to study the effect of sous-vide cooking of squid at different temperature combinations on a different color, textural, pH and cooking loss.

2. Materials and Methods
2.1 Materials
Experimental material was frozen squid, weighing 250 - 350 g, purchased from Hualian Supermarket of Xinxiang City. We selected the frozen Argentine squid of the same size, refrigerated and thawed, and washed the surface with a small amount of tap water. After that water was absorbed with filter paper, and the whole defrosted squid was separated into head, foot (wrist) and ketone body with scissors. The ketone body was divided into a mantle portion and a caudal fin portion, and the mantle portion was cut along the midline of the abdomen to remove the internal organs, and the quality of the mantle film was measured; the sample bag was dispensed into a vacuum bag, and vacuum was applied by a vacuum packaging machine (vacuum degree - 0.1 MPa), placed in a refrigerator at a temperature of 4 ± 1 °C for use.

The samples were vacuum packed and heated in water baths at 55, 60, 65, 70, 75, 80, and 85 °C for 300min. All cooked squid as well as raw ones as controls were quickly cooled and stored at 4 ± 1 °C, until to be used for measurements outlined below.

2.2 Methods
2.2.1 Texture
The samples were cut into cubes of 2 × 2 × 2 (length × width × height) cm by TA.XT Express material analyzer. The fish meat was determined by the physical analyzer. Measuring conditions were following: SMS P/50 probe, 2 mm/s pre-test speed, 2 mm/s test speed, 10 mm/s post-test speed. The ambient temperature was 20 - 25 °C and was measured three times in parallel.
2.2.2 Color
Using CR-400 chromatograph, the L* value, a* value and b* of samples were determined after white board calibration. Different cross-sections of each sample were selected for three times.

2.2.3 pH
Referring to GB 5009.237-2016, pH meter was used for determination. 10 g of sample was cut into pieces, 90 mL of distilled water with pH of 7 were added. Everything was soaked for 30 minutes and stirred continuously, and then tested with pH meter. After the value was stabilized, the number of samples determined was not less than 3.

2.2.4 Cooking loss
Cooking losses were calculated by the difference of weight before and after cooking and moisture content was determined by drying the samples (5 g) at 102 °C.

2.3.5 Statistical analysis
All the control and treatment groups were repeated three times. The data were analyzed by SPSS 19.

3. Results and Discussion

3.1 Texture
The texture is simulated by human oral chewing movement, using mechanical test methods to simulate texture changes [26]. Texture characteristics can effectively explain the texture changes that occur during the cooking process of squid, and currently can be used to objectively assess squid. Hardness and chewiness can directly reflect the tenderness of squid [27]. The size of the shear force parameters during heating is closely related to the changes in meat structure proteins [28]. Chewability reflects the difficulty of chewing food in the human mouth. The greater the chewiness value, the more laborious the food is in the process of eating [29]. The value of chewiness is the product of elasticity, hardness and cohesion. It can be seen from Table 1 that the hardness and chewiness of the squid decreased first and then increased with increasing heating temperature, and the difference was significant (p < 0.05).

The myofibrillar protein caused by heat treatment denatures and aggregates, shrinks, and the juice is slowly discharged from the cells [30]. As the heating temperature increases, more cell structure is destroyed, and the juice is more likely to be lost, resulting in the loss of juice. The magnitude of the increase in hardness value becomes larger [31]. The change of connective tissue is the main cause of increased hardness, collagen denaturation, further contraction of myofibrils, separation of muscle fibers from the intima and fascia [32].

Elasticity reflects the deformation of muscles under external force and the degree of recovery after decompression [33]. Myofibrillar protein [34] and connective tissue [35] are closely related to rheological properties such as muscle elasticity. It can be seen from Figure 1 that the when the heating temperature is 55 - 65 °C, the elasticity changes a little (p > 0.05), and the muscle elasticity of the squid is significantly increased when the temperature is raised to 75 °C (p < 0.05), which is inferred to be the action of heat. Fibrin forms a three-dimensional network that blocks some of the free water and forms a gel that is elastic [36]. As the heating temperature increases, the muscle elasticity of the squid decreases, which is due to the fact that the myofibrillar protein begins to degrade and the fiber structure becomes blurred. Other studies have shown that in the reduction of moisture content (10 - 40%), the elasticity of the squid slices decrease, and as the heating temperature increases, the heat further reduce the moisture content in the muscles of the squid [37]. On the other hand, some endogenous heat-stable proteases in the muscle decompose myosin, which destroys the degree of cross-linking of myofibrils [38], which also leads to a decrease in muscle elasticity of the squid. The results showed that the squid had better texture characteristics under heating at 60 °C.

Table 1. The changes in texture properties of squid during sous-vide cooking

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Hardness (g)</th>
<th>Springiness</th>
<th>Chewiness (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>12737.30 ± 702.99a</td>
<td>0.88 ± 0.04c</td>
<td>7766.66 ± 723.21a</td>
</tr>
<tr>
<td>55</td>
<td>6481.32 ± 211.94d</td>
<td>0.91 ± 0.01c</td>
<td>4695.33 ± 212.69d</td>
</tr>
<tr>
<td>65</td>
<td>4252.65 ± 1166.43e</td>
<td>0.95 ± 0.08c</td>
<td>3072.96 ± 864.35a</td>
</tr>
<tr>
<td>70</td>
<td>7720.73 ± 464.47cd</td>
<td>0.88 ± 0.06c</td>
<td>5436.86 ± 596.48cd</td>
</tr>
<tr>
<td>75</td>
<td>7056.86 ± 1110.89cd</td>
<td>2.70 ± 1.40a</td>
<td>5862.34 ± 834.95bcd</td>
</tr>
<tr>
<td>80</td>
<td>7391.20 ± 1807.18c</td>
<td>2.38 ± 1.59ab</td>
<td>6995.51 ± 1374.66ab</td>
</tr>
<tr>
<td>85</td>
<td>7519.92 ± 1163.15cd</td>
<td>1.32 ± 0.46cd</td>
<td>6464.84 ± 751.28abc</td>
</tr>
<tr>
<td></td>
<td>10878.61 ± 723.58b</td>
<td>0.85 ± 0.09c</td>
<td>7558.20 ± 1515.34a</td>
</tr>
</tbody>
</table>

Legend: Data are average of three determinations. Different superscript letters within the same row mean significant differences between the different temperatures (p < 0.05).
3.2 Color

Color is an important attribute that consumers first consider before deciding to purchase meat products [39]. The evaluation of L*, a* b* and whiteness parameters showed a significant difference (p < 0.05) (Table 2). L* increased first and then decreased with increasing temperature, and the highest brightness was 82.45 under heating conditions of 65 °C. Consumers prefer products with high brightness values. With the increase of heating temperature, a* and b* showed wave dynamic potential, and the difference was significant (p < 0.05). Whiteness is an important indicator for evaluating squid products. During the heating process, the whiteness of squid increased first and then decreased, the difference was significant (p < 0.05), and the whiteness was the highest at 65 °C, which was 89.53. The muscles of the squid do not accumulate fat, and it is mainly accumulated in the internal organs. The viscera oil content of the squid is extremely high, and the change of the color of the squid caused by heating has little to do with the presence and degradation of the lipophilic compound [40]. Dihord et al., [41], in the study of gigante (Dosidicus gigas) protein concentrates, showed higher whiteness indices above 82. The whiteness of cooking for the squid (Dosidicus gigas) fins, mantle and arms are higher than 88 [40].

3.3 pH

The pH of the meat product is an indicator of freshness. The pH value of the muscle of the squid was slowly increased and then decreased during the whole process, and there was no significant difference (p > 0.05). The initial pH of the muscle is 6.84, which is acidic, but generally the initial pH of the meat is weakly alkaline, which may be related to the sour taste of the muscle of the squid itself. As the heating temperature increases, it is weakly alkaline. When the heating condition is 85 °C, the pH value drops to 6.69 (Figure 1).

It may be that the heating time is too long. The glycogen decomposes in the anoxic environment to produce lactic acid [42], and the ATP degrades in an acidic environment. Phosphoric acid or the like is generated to lower the pH.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>Whiteness index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>63.63 ± 1.15a</td>
<td>-0.44 ± 0.12c</td>
<td>-2.37 ± 0.86g</td>
<td>83.9 ± 4.80ab</td>
</tr>
<tr>
<td>55</td>
<td>76.98 ± 0.38d</td>
<td>0.48 ± 0.25a</td>
<td>8.94 ± 0.38d</td>
<td>64.65 ± 6.06c</td>
</tr>
<tr>
<td>60</td>
<td>80.66 ± 0.66bc</td>
<td>0.13 ± 0.11bc</td>
<td>10.02 ± 0.88c</td>
<td>81.35 ± 9.00ab</td>
</tr>
<tr>
<td>65</td>
<td>82.45 ± 0.40a</td>
<td>0.98 ± 0.54ab</td>
<td>6.37 ± 0.49f</td>
<td>89.53 ± 0.88a</td>
</tr>
<tr>
<td>70</td>
<td>79.38 ± 0.92b</td>
<td>0.42 ± 0.34a</td>
<td>7.77 ± 0.32e</td>
<td>87.59 ± 4.28a</td>
</tr>
<tr>
<td>75</td>
<td>80.97 ± 0.94ab</td>
<td>0.75 ± 1.18ab</td>
<td>9.36 ± 0.48cd</td>
<td>78.38 ± 4.06ab</td>
</tr>
<tr>
<td>80</td>
<td>78.64 ± 1.46cd</td>
<td>0.83 ± 0.62ab</td>
<td>15.04 ± 1.16f</td>
<td>74.33 ± 8.55bc</td>
</tr>
<tr>
<td>85</td>
<td>77.05 ± 1.90d</td>
<td>0.71 ± 0.37ab</td>
<td>11.03 ± 0.40e</td>
<td>80.15 ± 6.17ab</td>
</tr>
</tbody>
</table>

Legend: Data are average of three determinations. Different superscript letters within the same row mean significant differences between the different temperatures (p < 0.05).

3.4 Cooking loss

Cooking loss generally refers to the decrease in mass and the loss of volatilization caused by the loss of heat and soluble substances and food solids as the heating temperature increases and the heating time increases. Water is the main loss component [43]. The cooking loss rate of squid was 50.08% at 55 °C (Figure 2).

As the heating temperature increased, the cooking loss rate also increased. The cooking loss rate of squid was 85.5% at 85 °C. As a result of heat-induced denaturation of myosin and actin, it changes the structure of myofibrillar proteins, causing muscle fluid to be excreted from muscle fibers, resulting in loss of water in muscle tissue [44]. Otwell, [45], studied the effects of cooking on mullet (Loligo pealei Lesuer) and found that the weight loss of squid after cooking was 50%, which is consistent with the results of this experiment.
4. Conclusions
- The results showed that the quality of squid with sous-vide cooking was significantly improved. With the increase of cooking heating temperature, the pH, hardness, elasticity, and chewiness of squid increased first and then decreased. The squid under 60 °C heating condition had better texture characteristics.
- Sous-vide cooking had a significant effect on the color and cooking loss of the squid (p < 0.05), and the squid had the least cooking loss under heating at 55 °C.
- Combining good changes in texture and cooking loss commended 60 °C as a superior sous-vide cooking environment.

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5. References


