Chemical, physical and sensory changes of small abalone meat during cooking

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ABSTRACT: Small abalone meats were heated at 80°C and 98°C for 0–120 min and the differences in chemical, physical and sensory changes of the cooked meats were investigated. The decrease in moisture and weight and the increase in browning and Hunter’s b-value were relatively higher for cooking at 98°C than at 80°C. After cooking for 20–120 min, the total amount of adenosine triphosphate and its related compounds on a dry weight basis decreased by 17–27% at 80°C and by 30–39% at 98°C; the total amount of free amino acids on a dry weight basis changed insignificantly at 80°C but decreased by 22–35% after cooking at 98°C. The meats cooked at 80°C were higher in cutting force whereas the levels in the samples cooked at 98°C did not decrease until samples had been cooked for 60 min. The hydroxyproline content showed little change during cooking except for in samples cooked at 98°C for 120 min, in which the content was found to be low. The extended cooking at 80°C improved the acceptability of small abalone meat, whereas only the acceptability score of aroma increased significantly for cooking at 98°C.

KEY WORDS: abalone, cooking, free amino acid, Haliotis diversicolor, sensory property, taste, texture.

INTRODUCTION

In the consumption of seafood, sensory properties are generally the most important factors affecting consumer acceptance.1,2 Abalone, with its unique flavor and texture, is a popular delicacy in the world. The odor, color, appearance and size are also important for the quality of abalone and its products.3,4 Abalone meat has a firm and crisp texture but exhibits a soft chewy texture after being canned or cooked for a long time – textural properties of abalone meat that are preferred in the market.3–5 As has been reported for abalone harvested during an annual cycle, those collected in summer are tender and have the lowest collagen content, whereas the winter samples are tough and have the highest collagen content.6,7 It has also been reported that the toughness and collagen content of abalone muscles vary among species and the relationship between them is roughly linear for the Japanese abalone muscle.6 In addition to raw muscle, the collagen in abalone meat decreases with a concomitant decrease in the hardness of meat during cooking.5 It has also been reported that the rheological properties and structure of cooked abalone meat differ from those in the raw and steamed meats.5,9 In contrast, changes in composition, extractive components, weight and browning of shellfish muscles have also been found to be related to cooking conditions.5,10–17 Particularly significant is the influence of cooking time on the sensory properties of cooked abalone and kuruma prawn meats5,12 and soup made from hard clams.14 The preferred properties are always associated with an abundance in taste components.

The contributions of extractive components to the taste of seafood have been reviewed.18,19 Glutamic acid (Glu), glycine (Gly), alanine (Ala), arginine (Arg), taurine (Tau) and adenosine monophosphate (AMP) are the taste-active components in snow crab,20 scallop21 and short-necked clam,22 whereas Glu, Gly, AMP and glycinebetaine are essential for abalone flavor.23 A discrepancy in Glu, Gly and AMP levels has also been found to be responsible for the difference in taste preference between the cooked meats of small abalone fed with different diets.24 As mentioned before, changes in the taste and textural properties of abalone and turban shell meats occur during cooking.5,8–10 Results of previous studies have shown that both temperature and time are important in heat-induced changes in...
quality in abalone and other shellfish. Therefore, in the present study, the chemical, physical and sensory changes of small abalone meat during cooking at 80°C and in boiling water (98°C) for 10–120 min were investigated. The selection of 80°C as the cooking temperature was because 80°C is high enough to bring about the denaturation of muscle proteins and to provide a sufficient and reasonable temperature gap for comparison with 98°C.

MATERIALS AND METHODS

Materials

Commercial-size small abalone *Haliotis diversicolor*, which were fed gracilar* Gracilaria* sp. were collected from August to November from culture farms in north-eastern Taiwan. The total weight including the shell, and the shell length of the samples were 20 ± 4 g and 5.5 ± 0.3 cm, respectively. The live specimens were acclimated in aerated seawater at ambient temperature for 2 h. Their shell and viscera were then removed. Five pieces of the raw edible meat were vacuum-packed in a polypropylene bag and cooked in 80°C water or boiling water (98°C) for 10, 20, 30, 60 and 120 min, respectively. The temperature of the central part of the meat reached 78°C after cooking at 80°C for 8–9 min and 98°C after cooking at 98°C for 11–12 min. Triplicate experiments were carried out separately to provide mean values.

After cooling at room temperature, the cooked meat was removed from the bag and used as a sample to measure weight, color, textural property and sensory evaluation. For the analyses of moisture, degree of browning, hydroxyproline (Hyp), adenosine triphosphate (ATP) and its related compounds, and free amino acids (FAA), the five pieces of cooked meat obtained from each treatment were pooled, cut into small pieces, mixed well, and then used as a sample.

Color measurement

Changes in surface color of the cooked meat were measured by Hunter's tristimulus color values (*L*, *a* and *b*) using a color difference meter (TC-1800MK-II; Tokyo Denshoku, Tokyo, Japan). Each sample was measured five times to obtain its mean value.

Degree of browning

Approximately 5 g of sample was homogenized in 30 mL of 7% cold trichloroacetic acid (TCA) for 2 min, centrifuged at 4000 xg for 20 min, and filtered. This procedure was repeated three times. The supernatants were then combined and made up to 100 mL. The absorbance at 420 nm (*A*420) was measured to express the degree of browning (*A*420/g) in the cooked meats.

Textural property

The meat sample was trimmed vertically along the direction of the muscle fibers into a 1-cm x 1-cm thick piece and measured by a Texture Analyzer TA-XT2 (Stable Micro Systems, Haslemere, England) with a knife-type plunger. The elevation speed of the sample tray was 1.0 mm/s. The force to cut through the surface of the 1-cm-wide meat was recorded and regarded as the cutting force to assess the textural change of the samples.

Hydroxyproline

The meat sample (0.1 g) was hydrolyzed in a vacuum with 2 mL of 6 mol/L of hydrochloric acid at 110°C for 20 h. Its Hyp content was determined by the colorimetric method of Woessner.25

Adenosine triphosphate and its related compounds

The ATP and its breakdown products, including adenosine diphosphate (ADP), AMP, inosine monophosphate (IMP), inosine (HxR), adenosine (Ado) and hypoxanthine (Hx) were extracted with 6% perchloric acid and analyzed by high performance liquid chromatography as described previously.26

Free amino acids

A TCA extract was prepared from the meat sample by the method of Konosu *et al.*27 The
Cooking of small abalone meat

Sensory evaluation

The cooked meat from each treatment was evaluated separately by an acceptance test. The samples were served in coded dishes and evaluated by 35 laboratory panelists. One sample was offered to each subject. The subjects were asked to rate the attributes of taste, aroma, color, texture and overall acceptability on the nine-point hedonic scale: 9 = like extremely; 5 = neither like nor dislike; 1 = dislike extremely. The data obtained from triplicate experiments were combined to calculate the mean acceptability scores of the samples.

Statistical analysis

Data were subjected to one-way ANOVA followed by Duncan’s multiple comparison test to identify differences among the means at P < 0.05 using Statistical Analysis System software (version 6.02).

RESULTS AND DISCUSSION

Changes in physical properties

Cooking of small abalone meat at 80°C and 98°C for 10–120 min resulted in a loss of approximately 4 and 9% of moisture and 11 and 20% of weight, respectively. The weight loss in the sample cooked at 80°C for 120 min was also high (Table 1). The abalone meat packed in a vacuum-sealed polypropylene bag and boiled for 15–60 min lost approximately 5% of moisture and 23% of weight, but only 61% of the original weight remained after boiling for 360 min. The abalone meat heated in boiling water or steamed for 1–3 h had a reduction of 3–6% moisture, and the weight decreased to 48–64% of its original value. The decrease in the weight of Japanese cockle foot by cooking has been reported elsewhere.

Hunter’s L-value (lightness) increased from 44.8 to 49.8 at 80°C and from 44.8 to 54.4 at 98°C after cooking for 10 min, and kept almost constant thereafter (Table 1). Hunter’s a-value declined slightly during the first 10 min of cooking, whereas Hunter’s b-value increased.

Table 1 Changes in moisture, weight, and color of small abalone meat during cooking at 80°C and 98°C (mean ± standard deviation)

<table>
<thead>
<tr>
<th>Cooking time (min)</th>
<th>Cooking temperature</th>
<th>Moisture (%)</th>
<th>Weight (%)</th>
<th>Hunter’s L-value</th>
<th>Hunter’s a-value</th>
<th>Hunter’s b-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>80°C</td>
<td>76.7 ± 0.6a</td>
<td>100 ± 0</td>
<td>72.3 ± 0.6b</td>
<td>-1.65 ± 1.8a</td>
<td>77.3 ± 1.2a</td>
</tr>
<tr>
<td>10</td>
<td>80°C</td>
<td>72.2 ± 0.8b</td>
<td>97.0 ± 1</td>
<td>72.4 ± 0.5b</td>
<td>-2.73 ± 1.1a</td>
<td>69.6 ± 2.2b</td>
</tr>
<tr>
<td>30</td>
<td>80°C</td>
<td>72.6 ± 0.9b</td>
<td>99.0 ± 3</td>
<td>72.6 ± 0.8b</td>
<td>-0.33 ± 1.33a</td>
<td>69.6 ± 2.2b</td>
</tr>
<tr>
<td>60</td>
<td>80°C</td>
<td>72.3 ± 0.8b</td>
<td>99.0 ± 3</td>
<td>72.6 ± 0.8b</td>
<td>-0.33 ± 1.33a</td>
<td>69.6 ± 2.2b</td>
</tr>
<tr>
<td>120</td>
<td>80°C</td>
<td>72.4 ± 0.4b</td>
<td>99.0 ± 3</td>
<td>72.6 ± 0.8b</td>
<td>-0.33 ± 1.33a</td>
<td>69.6 ± 2.2b</td>
</tr>
<tr>
<td>0</td>
<td>98°C</td>
<td>84.8 ± 2.1a</td>
<td>100 ± 0</td>
<td>89.9 ± 3.4a</td>
<td>-2.73 ± 1.1a</td>
<td>54.4 ± 2.3a</td>
</tr>
<tr>
<td>10</td>
<td>98°C</td>
<td>84.8 ± 2.1a</td>
<td>98.0 ± 2</td>
<td>89.9 ± 3.4a</td>
<td>-2.73 ± 1.1a</td>
<td>54.4 ± 2.3a</td>
</tr>
<tr>
<td>30</td>
<td>98°C</td>
<td>84.8 ± 2.1a</td>
<td>98.0 ± 2</td>
<td>89.9 ± 3.4a</td>
<td>-2.73 ± 1.1a</td>
<td>54.4 ± 2.3a</td>
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<td>60</td>
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<td>89.9 ± 3.4a</td>
<td>-2.73 ± 1.1a</td>
<td>54.4 ± 2.3a</td>
</tr>
<tr>
<td>120</td>
<td>98°C</td>
<td>84.8 ± 2.1a</td>
<td>98.0 ± 2</td>
<td>89.9 ± 3.4a</td>
<td>-2.73 ± 1.1a</td>
<td>54.4 ± 2.3a</td>
</tr>
</tbody>
</table>

Note: Differences among the means at P < 0.05 are indicated by letters a, b, c, and d.
markedly from -5.2 (blueness) to -0.3 at 80°C and from -6.2 to 0.34 (yellowness) at 98°C. On elongated cooking, Hunter’s b-value showed no change at 80°C but increased somewhat at 98°C. Consistent with the changes in Hunter’s b-value, meats cooked at 98°C were observed to color as the cooking time increased, whereas the meat color showed little change during cooking at 80°C. Therefore, changes in color and Hunter’s b-value could be ascribed to a non-enzymatic browning reaction that can proceed continuously at 98°C but that slows down at 80°C. The formation of browning in dried and canned products of scallop adductor muscle is thought to be mainly as result of the process of cooking. According to Kawashima and Yamanaka, glucose-6-phosphate content is closely related to the degree of browning (optical density at 450 nm) that occurs in the cooked scallop adductor muscle. In their study, they further confirmed that Tau and Ala were the key FAA responsible for browning, because only these two amino acids in the cooked scallop adductor muscle decreased. Absorbance at 420 nm is another measurement for eliciting the browning in foods as a result of the Maillard reaction. As shown in Fig. 1, the degree of browning in small abalone meat increased from the initial level of 1.6 to 3.4 during the first 10 min of cooking, and then reached 4.5 and 5.0 after cooking at 80°C and 98°C for 120 min, respectively.

The changes in cutting force and Hyp of raw and cooked samples are shown in Fig. 2. The mean value of cutting force increased from 1289 g to

Fig. 1 Changes in degree of browning (A_{420}/g) of small abalone meat during cooking at (●) 80°C and (○) 98°C. Data are mean ± standard deviation (n = 6). A_{420} means the absorbance at 420 nm.

Fig. 2 Changes in (●, ○) cutting force (n = 15) and ( ■, □) hydroxyproline content (n = 6) of small abalone meat during cooking at (●, ■) 80°C and (○, □) 98°C. Data are mean ± standard deviation. Different letters indicate significant differences (P < 0.05) among different cooking times.

Fig. 3 Changes in the level of ATP and its related compounds in small abalone meat during cooking at (a) 80°C and (b) 98°C. Data are mean ± standard deviation (SD) (n = 6). The bar at the top of the column indicates the SD of the total content. Different letters indicate significant differences (P < 0.05) among different cooking times. Ado, adenosine; ADP, adenosine diphosphate; AMP, adenosine monophosphate; ATP, adenosine triphosphate; Hx, hypoxanthine; HxR, inosine; IMP, inosine monophosphate.
1550 g after cooking at 80°C for 10 min. It did not decrease significantly at 98°C until the sample had been cooked for 60 min. Before cooking, the Hyp content was approximately 2 mg/g, suggesting that small abalone is low in collagen compared with other abalone species. On the whole, the changes in Hyp of small abalone meats during cooking were similar to that of cutting force. The observations, however, are inconsistent with the results of Hatae et al. who indicated that both collagen and breaking stress in abalone meat decrease after cooking for 15–360 min. Ochiai et al. also demonstrated that heat-induced tenderization of turban shell muscles occurs at temperatures between 50 and 70°C for 30 min and a decrease in toughness of the foot muscle is principally a result of heat denaturation or gelation of collagen. Gao et al. reported, as compared with raw meat, that decreases in the elastic modulus and rupture strength together with an increase in relaxation time of the abalone meat cooked in boiling water for 3 h are mainly caused by collagen being gelatinized during heating. According to Olley and Thrower, however, the conversion of collagen to gelatin in abalone is approximately 41% after boiling for 1 h. It is considered, therefore, that the increase in cutting force at 80°C for 10 min in the present study is possibly associated with muscle protein denaturation and a loss of moisture. As compared with Hatae et al., whole small abalone meat were used here, instead of the middle part of the abalone meat, for the determination of Hyp. In addition, the type of plunger and the elevation speed of the sample tray for measuring the textural property were also different. Oleachea et al. reported that abalone muscles high in collagen are tough and the collagen content varies among muscle parts – that in the dorsal surface of the foot being the highest, followed by the hard and soft

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**Fig. 4** Changes in the total amount of free amino acids in small abalone meat during cooking at (●) 80°C and (○) 98°C. Data are mean ± standard deviation (n = 6). Different letters indicates significant differences (P < 0.05) among different cooking times.

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**Fig. 5** Changes in the level of the major free amino acids in small abalone meat during cooking at (●) 80°C and (○) 98°C. Data are mean ± standard deviation (n = 6). Different letters within the same treatment indicate significant differences (P < 0.05) among different cooking times.
parts of the foot, and the upper and middle adductor muscle.

Changes in extractive components

The total amount of ATP and its related compounds (ARC) in small abalone meat on a dry weight basis changed slightly after cooking for 10 min, then decreased by 17–27% at 80°C and 30–39% at 98°C compared with its initial levels (Fig. 3). The ATP degraded during the first 10 min of cooking, whereas AMP increased and its level accounted for 66–77% of the total ARC in the cooked samples. There was also a fairly high amount of ADP but this decreased gradually during cooking at 98°C. There were low amounts of IMP and other breakdown products of nucleotides.

The cooking changes for the total amounts of FAA in small abalone meat are shown in Fig. 4. Based on dry weight, Tau, Arg, Gly, Glu, Ala, serine, glutamine and proline were the dominant constituents. The total amount of those FAA in all samples accounted for more than 90% of the total FAA. The FAA compositions obtained in the present study are almost the same as those reported previously. The total FAA and most of the major FAA changed insignificantly during cooking at 80°C. In contrast, the total amount of FAA decreased 22–35% after cooking at 98°C for 20–120 min. Levels of the major FAA, except for Gly and Glu, also tended to be reduced when the cooking time was extended (Fig. 5). Hatae et al. indicated that the total amounts of FAA in abalone meat and drip increased after cooking for 15–60 min. These authors also explained that the increases in FAA and oligopeptides in the cooked drip resulted from the hydrolysis of proteins by proteolytic enzymes prior to inactivation. Kawashima and Yamanaka indicated that the browning in the cooked scallop adductor muscle involved the participation of FAA such as Tau and Ala as the dominant reactants. But this was not found in the present study (Fig. 5) regardless of the fact that browning in small abalone meats occurred during cooking at 80°C and 98°C (Fig. 1). In the present study, cooked drip from the cooking of small abalone meats was also observed. The drip produced from cooking at 98°C was more than that at 80°C. This implied that increases of FAA in small abalone meat by proteolysis during the early period of cooking might occur. Consequently, the decrease in the total FAA during cooking at 98°C can be attributed to the fact that the loss of FAA in cooked drip was greater than the increase of FAA by proteolysis.

Adenosine monophosphate, Glu and Gly are considered to be the taste-active components in shellfish such as abalone, scallop and short-necked clam. The amount of AMP, which varies with different cooking conditions, has also been reported in relation to the difference in taste preference for the kuruma prawn muscle and the hard clam soup. Chiou and Lai compared the taste components in the cooked meats of small abalone fed gracilar or an artificial diet, and concluded that Gly, Glu and AMP were likely to be the key components responsible for the different tastes of the two meats.

Changes in sensory properties

The cooking of small abalone meats at 80°C for 10–120 min had a significant effect (P < 0.05) on the sensory scores for the different attributes of small abalone meat cooked at (a) 80°C and (b) 98°C for 10–120 min. Data are mean ± standard deviation (n = 105). Different letters within the same treatment indicate significant differences (P < 0.05) among different cooking times.
taste, aroma, texture and the overall acceptability of the cooked samples (Fig. 6). Their acceptability scores tended to increase gradually with the increase in cooking time. In contrast, changes in the acceptability score for color were insignificant. The meat cooked for 10 min was the lowest in overall acceptability. This could be mainly related to its low score in taste. When cooking at 98°C, only the effect on aroma was significant and the highest aroma score appeared after cooking for 120 min. The panelists commented that the sample's aroma was preferable because of the stronger characteristic flavor of canned abalone. As reported, the acceptability of the taste and odor of the abalone was significantly higher after cooking for 180 min than for 30 min.5

In conclusion, small abalone meat cooked at 98°C for 10–120 min showed relatively high decreases in moisture, weight, AMP and FAA and changes in color compared with that cooked at 80°C. The meat cooked at 80°C was also characterized by an increase in cutting force, whereas that cooked at 98°C had a cutting force similar to raw meat except that cooking was extended to 120 min. The increase in cooking time at 80°C improved the sensory preference of the samples, but improved only the aroma acceptability during cooking at 98°C.

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REFERENCES


