EFFECTS OF COOKING AND RINSING ON THE PROTEIN LOSSES FROM BLUE CRABS[1, 2]

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Abstract

The effects of cooking blue crabs at two temperatures (100 C and 121 C) on the amount of cook loss and concurrent protein loss were studied under controlled pilot plant conditions. The 121 C cook temperature resulted in a greater volume of cook loss fluids which contained a greater amount of protein. Centrifugation of the cook loss and analysis of the supernatant fractions showed that the protein in the supernatant from the 121 C cook was significantly greater than in the supernatant from the 100 C cook. Percent protein in the solids component of the cook loss showed an inverse relationship being slightly, but not significantly, higher in the solids from 100 C cook than in the 121 C cook. Under pilot test conditions, rinsing samples of fresh picked crab meat with tap water resulted in protein losses of 15.2% for the 100 C cook and 12.6% for the 121 C cook. Dipping crab meat samples in a salt brine solution resulted in protein losses of 11.2% for the 100 C cook and 7.3% for the 121 C cook. Higher protein losses during the early winter season were attributed to seasonal variation in the physiological condition of the blue crab.

Little research has been done characterizing the wastes from blue crab processing. The liquid which is produced during processing of blue crabs (*Callinectes sapidus*) is not generally utilized but is discharged from the processing plant as waste material. Approximately 86% of the whole crab is not used for human consumption. Solid wastes have been processed and sold as animal feed or fertilizer. The liquid losses from blue crab processing can be generated during washing, rinsing, cooking, meat extraction, and, sometimes, cooling processes. Major concerns, therefore, are to find ways of either reducing or eliminating production of waste materials, *per se*, or to find uses for these wastes as saleable by-products. The liquid wastes have not been characterized as to their proximate composition.

Processes to which fish and shellfish are subjected, such as cooking, chilling, and freezing, have an effect on the amount of protein that will be lost. Major losses can be attributed to contact with processing waters or by direct loss of moisture from the muscle due to the type of process. Liquids lost during processing are considered to be exudates as contrasted to drip loss which is usually associated with the freeze-thaw cycle *(8)*. Studies on the composition of drip loss showed that a relatively high amount of nitrogen-containing compounds were lost as the result of freezing and thawing crab meat *(3)*. This research *(3)* further indicated that the amount of protein which was soluble in a 5% NaCl solution was 42.7 g/100 g for *Neptunus pelagicus*. These results generally confirmed those reported for fish *(10)* wherein 40, 53, and 48 g of protein/100 g of total protein were extracted with 5% NaCl from pomphet, surmai, and mackeral, respectively. Cod muscle resulted in 18.75 g protein/100 g being extracted, of which 22% was water soluble (sarcoplasmic) by using a 0.5 μ buffer solution *(5)*. The extraction of soluble protein *(7)* from calico scallop meats resulted in from 24.4% to 31.5% of the total protein extracted, depending on the manner in which the raw product was processed *(13)*. The level of extractable protein from various fishery products has been summarized *(2)*, but data on the component proteins of the blue crab are virtually nonexistent. Commercial processing of the blue crab is believed to be prone to the loss of significant quantities of protein.

The commercial processing of blue crabs usually entails cooking live crabs under pressure (15 psi) for approximately 10 min at 121 C. In some states this time/temperature relationship is required by regulation. The crabs are subsequently air chilled but in some instances they are chilled by cold water rinsing. The meat is extracted (picked) from the chilled crab by either hand or mechanical methods. In recent years, the product is often exposed to tap water or salt brine during the extraction process. Briefly, the crab claws, legs, viscera, and back are removed and the component parts conveyed by flowing tap water. Subsequently, the meat is extracted by either hand picking or mechanical systems. Us-

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ually the cores are hand picked while the meat from the claws is mechanically extracted by maceration and salt brine flotation to separate the meat and shell. More recently extensive mechanical separation has been accomplished on the whole crab with the extensive use of rinse waters and/or salt brine solutions. These systems expose the crab meat to liquids which potentially allow for extraction of soluble proteins.

Studies by the National Marine Fisheries Service *(6)* have indicated that the meat extracted from crabs cooked at 100 C for approximately 8 min was of a higher quality when subjected to frozen storage. However the need for further studies on this process were indicated. Determination of the adequacy of cook has been based on developing a firmness of texture and subsequent release of meat from the shell to allow easy picking and increased meat yields. Preliminary work in this laboratory has indicated that relatively low temperature/short time (100 C for 8 min) would not be sufficient to meet these criteria.

The objectives of this study were to investigate the amount of protein contained in the exudate from the cooking process and the effect of controlled rinsing and dipping operations on the amount of protein lost under simulated pilot processing methods for the blue crab.

EXPERIMENTAL PROCEDURES

Sampling

Since most crab processing plants are not equipped for precisely controlling the factors studied in this experiment, the work was done in the pilot laboratory of the Food Science Department, where exact temperatures and times, as well as volumes of water used or lost, could be recorded. Samples of live blue crabs were harvested from the sounds and rivers of Pamlico County, North Carolina. Crabs were transported to the laboratory in an open ice chest, underlined with ice and burlap within 12 hr after harvesting. When ambient temperatures exceeded 55 F (12.8 C), crabs were covered with wet burlap.

Sample preparation

Ten trials were completed over a period of 5 months. Market size crabs were randomly divided into two lots of 15 each, with no special selection being made for sex. Crabs were steamed from the live state within 24 hr following harvesting. Lots were randomly assigned in two treatments: *(a)* steaming at 100 C for 8 min and *(b)* steaming under pressure (15 psig) at 121 C for 10 min. After steaming, crabs were individually removed from the cooking container, drained free of excess fluid, and subsequently transferred to another pan and covered for air cooling overnight at 1.6 C. The liquid, along with any solidified material remaining in the cook loss fluids, was measured to determine volume of cook loss and refrigerated for subsequent analyses. Cook loss fluid from the steaming operation was blended in a Sunbeam blender, an aliquot taken for subsequent analyses and the remainder centrifuged for 10 min at 7970 × g at a temperature of 5 C. The supernatant was decanted and each fraction saved for subsequent analyses. Macro- and micro-Kjeldahl analyses were done on the solid and supernatant fractions, respectively.

Chilled crabs were hand picked to remove only the lump meat. A 150-g sample of the meat was randomly selected from each lot (15 crabs) for use in the rinsing studies. Rinsing procedures were designed to simulate the rinsing of crab meat with tap water (as is practiced in some commercial operations).

To obtain values for protein lost during rinsing of the crab meat with tap water, a rinsing apparatus was constructed as illustrated in Fig. 1. A pressure pump was used to pressurize the 5-gal Nalgene bottle so that the water pressure could be controlled through a preset nozzle. The bottle was connected to the nozzle with 0.5-inch plastic tubing. A brass, garden-type spray nozzle was used to produce a spray to cover the desired circular area. The nozzle was adjusted to a height of 15 inches above the product and this produced a spray covering 8 inches in diameter. The pressure was set at 18 psig, which delivered 1550 ml water in 1.5 min. The crab meat sample was uniformly spread on a wire screen (8 inches in diameter, .0937 in^2 opening, Tyler equivalent 8 mesh) to allow good drainage and still restrict actual loss of whole pieces of meat. Each sample was rinsed for 15 min. The rinse water was collected and analyzed for nitrogen (protein).

A 150-g sample of the meat was randomly selected from each lot to study the effects of immersion of crab meat in NaCl brine (as encountered in the mechanical method *(4)* of meat extraction). To estimate losses of protein by the mechanical method of extracting crab meat, a simulated pilot system was used whereby 150 g crab meat were dipped into 1550 ml of an 8% NaCl brine solution for 10 sec. The meat was removed and allowed to drain until dripping essentially ceased. The brine solution was analyzed for total nitrogen.

Analytical methods

The solids from the centrifuged cook loss fluid were analyzed for nitrogen by the macro-Kjeldahl procedure with slight modification *(1)*. The modifications consisted of drying the samples for 16 hr at 107 C in a vacuum oven and subsequently digesting in 40 ml of concentrated H_2SO_4, in the presence of a pre-measured catalyst (Kel-Pak, No 5). Rinse water, brine dip solution, and cook loss fluid (total and supernatant) were analyzed by the micro-Kjeldahl procedure *(1)*. All samples were analyzed in duplicate and a blank was done with each determination. The pH values were determined with a Leeds and Northrup 7405 glass electrode pH meter. Moisture, fat, and ash content of fresh crab meat were determined *(1)* and statistical analyses were done on the data *(10)*.

RESULTS AND DISCUSSION

The mean and standard error of the mean of the cook loss resulting from the cooking of whole crabs at 100 C and 121 C are given in Table 1. Although the amount of fluid which was collected as cook loss varied among different lots within temperature treatments, as noted by the standard errors, the differences were not significant. The physical condition of the crabs probably affected the amount of fluid lost, causing the observed variation within lots. Crabs which appeared to have just molted tended to exude less than crabs which were not molting. Other conditions, such as the amount of food in the crab's entrails may have affected the volume of cook loss.

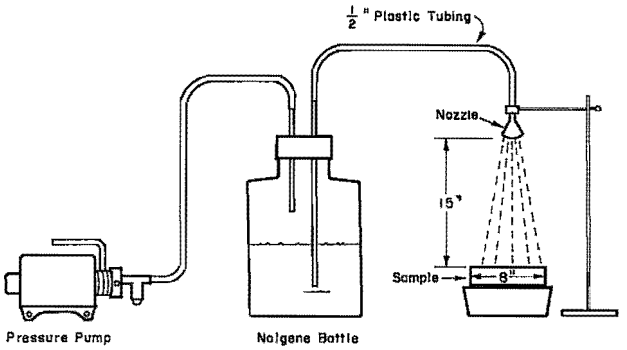

Figure 1. Schematic diagram of the rinsing apparatus.

TABLE 1. EFFECT OF COOKING TEMPERATURE ON COOK LOSS OF BLUE CRABS

Temperature of steaming (°C)	Average sample weight (g)	Cook loss[a] (ml)	Cook loss (%)
100	2208.6	211.5 ± 40.3[b]	9.58[b]
121	2066.6	429.5 ± 40.3[b]	21.30[b]

[a]Expressed as the mean and standard error of 10 trials (lots).
[b]Significantly different at 0.01 level. Values for cook loss were calculated from the cook loss and initial sample weight data.

TABLE 2. PROXIMATE COMPOSITION OF COOKED MEAT FROM THE BLUE CRAB

Component	%
Moisture	77.08
Protein	18.42
Fat	2.48
Ash	2.02

Crabs with missing appendages often exuded a white proteinaceous material from the resultant opening although this condition was minimal. The difference between cooking temperatures was highly significant at the 0.01 level. Differences in cooking conditions were minimized by adjusting the steam by-pass on the autoclave and the subsequent slow (5 min) release time of steam pressure. The increase in loss for the 121 C cook temperature was attributed to the increased temperature and pressure and the apparent stress on the component parts of the crab, especially the viscera. The higher temperature and pressure (15 psig) probably ruptured cells or cellular structure to a greater extent than the 100 C cook temperature causing the loss of more fluid. The greater severity of the higher temperature, higher pressure, and slightly longer cook time could also have caused more denaturation of proteinaceous material and the subsequent loss of fluid due to a reduction in water binding capacity.

The pH values indicated that the cook loss fluids were slightly acidic for both treatments (6.85 for 100 C, 6.86 for 121 C). The cook loss fluids were not significantly different in pH for the two cook temperatures. This indicated that cook temperature did not significantly change the acid concentration due to the release of amino or organic acids. This may be explained by the proteins in the solutions acting as strong buffers. The pH of whole, raw crabs was found to be 7.1 - 7.2 and it was found to be 8.0 for whole cooked crabs (cooked at 121 C for 10 min). This difference indicates that cooking the crabs caused changes in the pH which may be attributed to such factors as the release of organic acids or denatured proteins giving up bound cations. The rise in pH of the cooked crab to 8.0 may have been due to reduced buffering capacity of the heat denatured proteins.

The proximate composition of the cooked meat from blue crabs is presented in Table 2. These data were determined for use in establishing a basis for protein levels lost in the rinsing and dipping experiments. The amount of protein in the cook loss and the composite centrifuged fractions (solid and supernatant) of the cook loss are shown in Table 3. The values for protein reported in this study were based on an analysis for total nitrogen × 6.25. It was recognized that all of the nitrogenous material may not have been proteinaceous. The amount of protein in the supernatant of the cook loss from the 121 C cook was significantly higher than from the 100 C cook. The percent protein in the solids (centrifuge residue), however, showed an inverse relationship, the protein being slightly, but not significantly, higher in the solids from the 100 C than the 121 C cook. There were no significant differences among trials within the fractions, thus indicating that the sampling procedures were valid estimates of the population. The higher percentage of protein in the fluids from the 121 C cook was most likely related to the factors indicated as causing the greater cook loss for this treatment.

The amount of protein lost due to cooking was also expressed on the basis of the weight of the whole, raw crabs. Table 3 shows that the protein in the cook loss of the 121 C cook was significantly greater than the protein in the cook loss from the 100 C cook, when based on raw crab weight (mg protein/g crab). Thus, both percent cook loss and percent protein within the cook loss increased significantly for the higher temperature.

The data for protein losses due to tap water rinsing and NaCl dipping under pilot laboratory conditions are given in Table 4. The data for individual trials are presented to indicate the degree of variability, since significant differences were found among trial lots. The rinse water used for rinsing the meat from crabs steamed at 100 C had a larger percentage of protein in it than did the rinse water used for the

TABLE 3. EFFECT OF COOKING TEMPERATURES ON THE AMOUNT OF PROTEIN LOSS IN VARIOUS FRACTIONS OF THE COOK LOSS FLUID

Treatment (°C)	Sample fraction	Number[a]	Protein[b] (%)	Protein loss (mg) per g raw crab[c]
100	Total cook loss	28	3.1 ± 0.2[d]	2.9
	Supernatant	30	1.9 ± 0.2[e]	2.3
	Solids (dry residue)	16	74.4 ± 2.8[e]	0.6
121	Total cook loss	29	4.4 ± 0.2[d]	9.4
	Supernatant	30	3.3 ± 0.2[e]	6.9
	Solids (dry residue)	19	67.9 ± 2.6[e]	2.6

[a]All trials were done in triplicate, except the 121 C solids fraction was done in duplicate.
[b]Data are presented as mean and standard error of the mean.
[c]Calculated values.
[d]Significantly different at 0.01 level.
[e]Significantly different at 0.05 level.

TABLE 4. EFFECT OF COOK TEMPERATURE ON THE AMOUNT OF PROTEIN LOSS DURING TAP WATER RINSING AND 8% NaCl DIPPING OF BLUE CRAB MEAT

Cook temperature (°C)	Trial number and date[a]	Tap water rinse		8% NaCl dip	
		(%)[b]	Mg/g crab meat	(%)[b]	Mg/g crab meat
100	1 (Nov. '71)	0.17[c]	17.6	0.42[d]	43.4
	2 (Dec. '71)	0.51[d']	52.7	0.44[d]	45.5
	3 (Dec. '71)	0.72[d']	74.4	0.40[d]	41.3
	4 (Jan. '72)	0.19[c]	19.6	0.10[c]	10.3
	5 (Jan. '72)	0.22[c]	22.7	0.13[c]	13.4
	6 (Jan. '72)	0.26[c]	26.9	0.24[c]	24.8
	7 (Jan. '72)	0.14[c]	14.5	0.14[c]	14.5
	8 (Jan. '72)	0.18[c]	18.6	0.10[c]	10.3
	9 (Jan. '72)	0.18[c]	18.6	0.11[c]	11.4
	10 (Jan. '72)	0.18[c]	18.6	0.13[c]	13.4
	$\bar{X}$	0.28 ± .02	24.8	0.22 ± .02	22.8[c]
121	1 (Nov. '71)	0.14[c]	14.5	.25[d]	25.8
	2 (Dec. '71)	0.37[d']	38.2	.20[d]	20.7
	3 (Dec. '71)	0.44[d']	45.5	.25[d]	25.8
	4 (Jan. '72)	0.18[c]	18.6	.09[c]	9.3
	5 (Jan. '72)	0.21[c]	21.7	.11[c]	11.4
	6 (Jan. '72)	0.17[c]	17.6	.11[c]	11.4
	7 (Jan. '72)	0.20[c]	20.7	.10[c]	10.3
	8 (Jan. '72)	0.20[c]	20.7	.11[c]	11.4
	9 (Jan. '72)	0.15[c]	15.5	.09[c]	9.3
	10 (Jan. '72)	0.12[c]	12.4	.10[c]	10.3
	$\bar{X}$	0.22 ± .02	22.5	0.14 ± .02	14.6[d]

[a]Each trial was conducted in triplicate.
[b]Each sample consisted of 150 g crab meat rinsed with 1,550 ml of tap water or dipped in 1,550 ml 8% NaCl. Data are expressed as mean and standard error of the mean. Means which have different suffixes (c, d, d') were significantly different. d' Designation indicates significance at the 0.01 level, whereas differences at the 0.05 level are indicated by c and d.

crabs steamed at 121 C. This difference in protein of the tap water rinse was not significant between temperatures of steaming but there was a highly significant difference (0.01 level) among trials. The percent protein for each trial ranged from 0.12 to 0.26%, except for trials 2 and 3. The percent protein in the rinse water of these two trials was significantly higher, ranging from 0.37 to 0.72%. The crabs used in these two trials were the only crabs harvested during the month of December, crabs for the other trials being harvested almost a month before or after these trials. The physiological condition of the crab is known to be cyclic. Immediately after molting, the crab's body expands in size by the copius intake of water with a consequent increase in the volume of the body fluids *(9)*. Although molting was not obvious, data in Table 4 suggest that a major physiological change had taken place. On the basis of previously reported data *(12)*, it was concluded that the higher losses from the December-harvested crabs were due to a seasonal variation in the physiological condition of the crab, not necessarily molting, with a consequent difference in the meat. Therefore, the total proteinaceous losses might be expected to be greater during these periods.

By calculations, similar to those used to derive the

results for Table 3 for the cook loss data, the total amount of protein lost in each rinse can be determined, as well as the amount of protein lost per unit weight of crab meat rinsed. For the crabs cooked at 100 C, the meat lost 28.4 mg protein/g meat rinsed. The meat from the crabs cooked at 121 C lost 22.5 mg protein/g meat rinsed. On the basis of the analysis of steamed and picked crab meat (18.42% protein, Table 2), these losses are equivalent to 15.2% of the total protein for the 100 C cooked crabs and 12.6% of the total protein for the 121 C cook crabs. The data indicate that the cooking procedure using the higher temperature removed more of the soluble protein than occurred with the 100 C cook. Thus, if the protein was not lost during the cook, it was removed during the rinse. This would account for the greater amount of protein in the rinse solution of the 100 C cooked crab meat. The pH values of the rinse waters from the two treatments were not significant (6.36 for 100 C and 6.59 for 121 C) but were slightly lower than the pH of the cook loss fluids.

Crabs steamed at 100 C lost significantly greater amounts of protein in the salt brine dipping process than those steamed at 121 C. This followed a similar trend but to a greater degree than for the tap water rinse. There was a significant difference among the trials as illustrated in Table 4, showing that trials 1, 2, and 3 had the greatest protein loss within both treatments. As stated for the tap water rinsed samples, these trials were made using crabs harvested in late fall and early winter. The pH values for the salt dip solution after dipping the crab meat were not significantly different between the two cook temperatures (6.73 for 100 C and 6.51 for 121 C). The pH values for the cook loss fluids, tap water rinse, and salt brine dip were all lower than the cooked crab meat (pH 8.0). This indicated the removal of primarily acidic components from the crab meat under these simulated processing conditions.

The total amount of protein lost in the salt brine dip was less than the amount lost in the tap water rinse but the differences were greater for the latter technique. The tap water rinse utilized a pressurized spray, which contributed some physical action to the rinsing process; whereas, in the dipping process, no agitation other than that involved in lowering and raising the product into the solution was involved. The amount of protein leached out of the crab meat by the salt brine dipping operation was similarly important. The 22.8 mg protein lost per gram of crab meat which had been cooked at 100 C amounted to a loss of 11.2% of the total protein of the dipped crab meat and the 14.6 mg protein lost per gram of crab meat which had been cooked at 121 C was equivalent to 7.3% of the total protein.

The total protein content of the crab meat was substantially reduced by the rinsing and dipping treatments. These losses are major considerations in nutritive value as well as pollutional load strength for crab processing plants. When these losses are combined with the amounts lost during the cooking operation, the total represents a sizable fraction of the total protein of the crab. This investigation did not attempt to establish specific acceptable levels of protein which might be lost during processing. The results present rather conservative levels of protein loss under laboratory pilot conditions as compared to commercial operations. It appears that the losses observed in this study indicate the need for developing crab processing systems which will reduce the loss of protein.

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