

Processing Technologies and Their Effects on Microbiological Properties, Thermal Processing Efficiency, and Yield of Blue Crab

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Introduction

The fresh blue crab, *Callinectes sapidus*, industry must contend with a labor intensive, high quality, perishable product. Consequently, crab processors must strive to minimize production costs while maximizing production yields, product quality, and shelf life. Obviously, the ideal process would be one in which all these parameters were mutually compatible, or at least where no single parameter excluded another.

The blue crab industry's situation is unique in the animal food products processing industry. Most other products need only minimal handling after taking any step to reduce the bacterial population (i.e., cooking). However, in the blue crab industry the most intensive

handling of the product occurs after cooking. To compound the problem, crabs are traditionally debacked and eviscerated after cooking, which presents an opportunity for microorganisms not destroyed during cooking to contaminate meat surfaces, pickers' hands, and utensils. This contamination, therefore, may result in crab meat that can periodically be found to exceed the bacteriological criteria established by state regulatory agencies, and as a consequence shorten the shelf life of the product.

Currently, the industry processes live crabs either with steam under pressure or in boiling water. Some states, such as Maryland, North Carolina, and Florida, have regulations which stipulate that "crabs shall be cooked only under steam pressure" (Maryland Department of Health and Mental Hygiene, 1977; North Carolina Department of Human Resources, 1977; Florida Department of Natural Resources, 1977). Other state regulations stipulate cold-point temperature minimums (i.e., the rules governing crab meat operations in North Carolina require that "crustacea shall be cooked under steam pressure until such time that the internal temperature of the center-most crustacean reaches 235°F" (North Carolina Department of Human Resources, 1977)). Other state laws are less stringent as they do not specify cooking requirements or simply state that "crabs shall be cooked so as to provide a sterile crab" (Texas State Department of Health, 1969).

Cooking live crabs in a steam retort is the most common method of processing (Phillips and Peeler, 1973). However, a

major problem here is a lack of time and temperature uniformity among processors. Phillips and Peeler (1973) reported cook times ranging from 7 to 23 minutes at approximately 121°C (15 psi), and Ulmer (1964) reported cooking times from 3 to 20 minutes at 121°C. Furthermore, Dickerson and Berry (1976) reported steam temperatures ranging from 115.5°C to 121°C.

Another method commonly used in crab processing, particularly along the Gulf and South Atlantic coasts, is boiling. Although the temperature variations would not be as extreme as pressure steaming, there is considerable variation in the cooking times. Tinker and Learson (1972) reported cook times of 10-15 minutes while Ulmer (1964) reported times of 15-20 minutes.

Irrespective of method, cooking has three major effects. It 1) coagulates protein, which in turn loosens the meat from the shell to facilitate picking; 2) produces characteristic flavor of cooked crab meat; and 3) destroys many of the bacteria associated with the live crab (Ulmer, 1964).

This study explored blue crab processing methods and evaluated the impact of the processing variables on the microbiological character of the product, energy efficiency, and product yield.

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ABSTRACT — Crabs which were debacked and eviscerated before boiling showed no bacteriological advantages when compared with the traditional methods of boiling (i.e., whole-boiled; whole-boiled, debacked, and washed). There was, however, an apparent time advantage: Debacked and eviscerated crabs achieved the same processing level of the traditional processes in 35 percent less time.

Total meat yields were unaffected by the type of process; however, when compared by type of meat, a difference was detected. Flake meat from whole-boiled crabs yielded significantly more ($\alpha = 0.05$) meat than did the two other processes. Apparently, the absence of the shell in the debacking processes exposed the flake-meat areas to more excessive desiccation during refrigerated storage (3.3°C) prior to removal of the meat.

More specifically, we assessed the impact debacking and eviscerating the crab before processing had on these parameters as compared with the more traditional processing techniques. This new approach would bring blue crab processing in line with the sequence of events used in processing most other animal food products.

Materials and Methods

Raw Material

Crabs used in this study were obtained over 1.5 years and were harvested by potting and dredging. The crabs were harvested in the lower Chesapeake Bay and its estuaries and landed in Hampton, Va. The crabs were obtained from a local processor as they were being weighed off the boats. These crabs were then processed under the different experimental conditions on the same day they were harvested.

Processing

Crabs were brought back to the Virginia Polytechnic Institute and State University (VPI&SU) Food Science and Technology Department's Seafood Processing Research and Extension Unit Laboratory in Hampton, Va., for processing. There, the crabs were divided into groups for processing. The treatment processes follow.

Whole-Boiled, Debacked, and Washed

Whole crabs were cooked in boiling water for 10 minutes, removed, and placed in a sanitized plastic basket to cool at room temperature for 1 hour. Then they were debacked and eviscerated, and the visceral cavity was washed with a stream of water from a rubber hose with a jet nozzle. The crabs were then placed in another sanitized basket and stored at 3.3°C in a cooler overnight (about 12 hours).

Whole-Boiled

Whole crabs were cooked in boiling water for 10 minutes, removed, and placed in a sanitized plastic basket and stored at 3.3°C in a cooler overnight (about 12 hours).

Debacked, Eviscerated, and Boiled

Crabs were debacked and eviscerated live and then cooked in boiling water for 10 minutes. Crabs were then placed in a sanitized plastic basket and stored at 3.3°C in a cooler overnight (about 12 hours).

Steam Process

Whole crabs were cooked in a steam retort for 10 minutes at 121°C (15 pounds psi). The cooked crabs were placed in a sanitized plastic basket and stored at 3.3°C in a cooler overnight (about 12 hours).

Yield

After overnight cooling at 3.3°C, the crabs were weighed in the baskets and given to a professional crab picker for meat removal. The meat from each cook process was separated by type (flake, lump, claw) for yield determination.

Temperature Monitoring, and F_{250} Calculation

Temperatures of the cooking environments (water and steam), as well as the internal temperature of the crab's backfin muscle, were obtained with a Monitor Labs¹ Model 9300 twenty-channel temperature recorder coupled to copper constantan thermocouples.

The thermocouples were placed in the muscle of the swimming leg, by inserting the sensing end of the thermocouple through the outer membrane into the backfin muscle. The temperature recorder was programmed to print a temperature reading of the cooking vessel and crabs every 15 seconds. The data were used to calculate the F_{250} value of the various processes.

A computer program "on-line" at the VPI&SU computer center was used to calculate the F_{250} of the cooking process. The reference Z value used in the calculation was 18.

Microbiological Analysis

Microbiological analyses were per-

formed on samples taken from the various cooking processes for the following: Aerobic plate count, (APC), coliform MPN, fecal coliform MPN, coagulase positive *Staphylococcus aureus*, *Vibrio parahaemolyticus*, and *Vibrio cholerae*. Due to the rigorous heating, we felt it necessary to test only samples taken from the steam process for APC, coliform MPN, and fecal coliform MPN. Procedures used in the performance of these tests were those outlined in the "Bacteriological Analytical Manual for Foods" (USFDA, 1978). Exception to these was in the analysis of APC's where surface plating procedures were used, and in the counting of *V. cholerae* where direct plating onto thiosulfate citrate bile salts sucrose agar (TCBS) was used after blending and diluting in alkaline peptone water. Additionally, suspect *V. parahaemolyticus* and *V. cholerae* colonies were picked off TCBS plates onto triple sugar iron agar slants (with NaCl for *V. parahaemolyticus* isolates); if typical reactions of the isolates were observed on these slants, then the organisms were said to be *V. parahaemolyticus*-like, or *V. cholerae*-like.

Results and Discussion

Heat penetration curves representative of the "whole-boiled" crabs and the "debacked, eviscerated, and boiled" crabs are presented in Figures 1 and 2, respectively. The results show more rapid heat penetration into crabs which have been debacked and eviscerated before cooking. This is due to the reduction in mass of the debacked and eviscerated crabs, which results in a more intimate contact of the crab muscle with the heating medium (boiling water) and therefore more rapid heat penetration into the muscle. The reduction in mass is significant and ranges from 23.1 percent to 36.3 percent of the total weight of the crabs.

The loss of a significant portion of the crab's mass before boiling implies that the process might be shortened and yet achieve a process equal to that of whole crabs boiled for a full 10 minutes.

The heat penetration data after 10 minutes of boiling whole crabs produced an F_{250} range of 0.0009 to

¹Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA

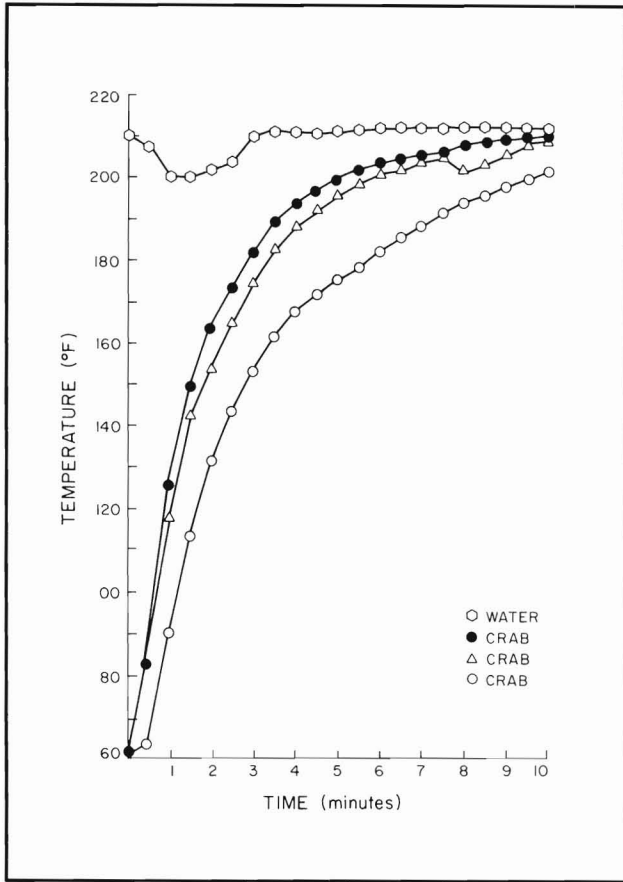


Figure 1.—Heat penetration curves for whole-boiled crabs.

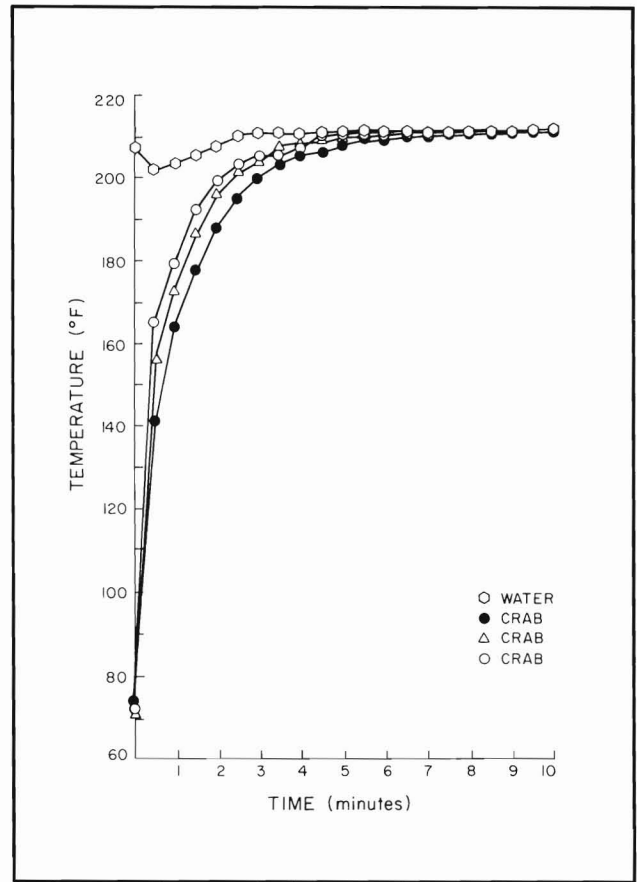


Figure 2.—Heat penetration curves for debacked, eviscerated, and boiled crabs.

0.0649. The average F_{250} was 0.0137, with a standard deviation of 0.0139. By comparison, the data for the “debacked, eviscerated, and boiled” crabs produced an F_{250} range of 0.0043 to 0.0602, with an average F_{250} of 0.0351 and standard deviation of 0.0124, thus indicating greater level of heating and less processing variability.

Assuming that the desired F_{250} value was 0.0137 (the average F_{250} for the “whole-boiled” crabs), this processing level was achieved in the debacked crabs in an average time of 6 minutes and 26 seconds. Hence, the possibility exists of shortening the processing time by about 35 percent.

A representative heat penetration curve for whole crabs steamed at 250°F for 10 minutes is shown in Figure 3.

Steamed crabs obtain a considerably higher F_{250} than boiled crabs. The F_{250} for steamed crabs ranged from 3.8088 to 8.5150. The F_{250} of steamed crabs before initiation of the cook time was as great or greater than the final F_{250} values achieved in some of the boiled crabs.

A significant factor in potentially reducing the processing time of crabs, particularly whole vs. debacked crabs, is the microbiological quality of the finished product. Figures 4 and 5 are representative of the bacteriological profiles encountered during the processing stages of “whole-boiled”, “debacked, eviscerated, boiled”, and “whole-boiled, debacked, and washed” crabs. Although differences in the geometric means of the bacteriological indices were observed, no statistical signifi-

cance, at $\alpha = 0.05$, was detected with any of the bacteriological indices at any stage of processing, irrespective of process. Though not statistically significant, the geometric means of the APC, coliform, and fecal coliform analyses were higher on the raw debacked crabs than on the raw whole crabs. This finding is contrary to what might be anticipated, since removal of the shell and a major portion of the viscera should reduce the total bacterial load. Under ideal conditions, the knives and hands of the people debacking the crabs would be sanitized between each crab. These practices were not used in this study, however, since it simulated commercial conditions where speed and volume are critical to commercial viability.

Debacking and eviscerating cooked

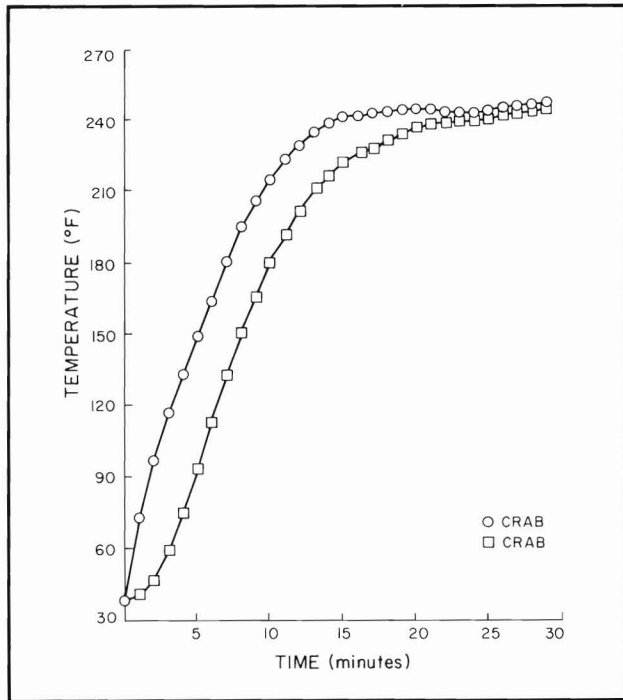


Figure 3.—Heat penetration curves for whole crabs steamed at 121°C.

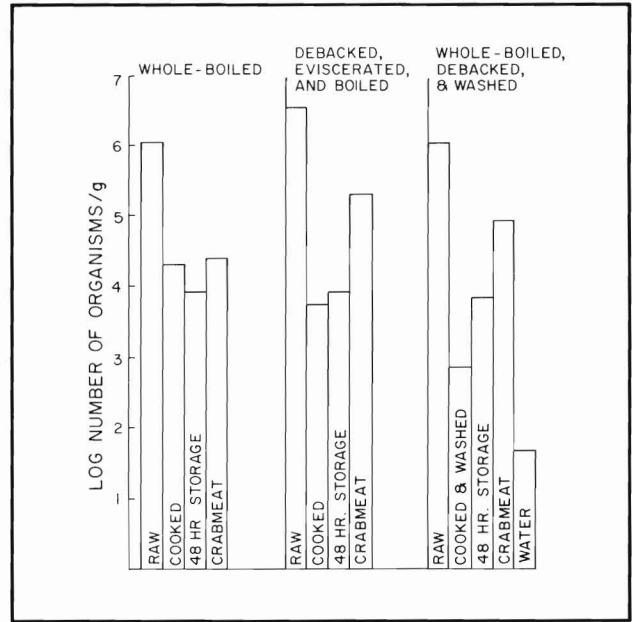


Figure 4.—Aerobic plate counts for whole-boiled; debacked, eviscerated, and boiled; and whole-boiled, debacked, and washed crabs (v = less than).

crabs followed by washing with running water did not improve the bacteriological quality of the product. This is in contrast to the suggestion by Ulmer et al. (1959); however, while the results of our study did not confirm the findings of those researchers, it also did not prove that washing the crabs would harm the bacteriological quality of the meat.

Our study also found it useful to run water through the hose for at least 5 minutes before washing the crabs to rinse away bacteria built up within the hose and/or nozzle while idle. During one study, bacterial numbers from a hose which had been idle for 7 days had an APC of 1.0×10^6 organisms/ml, and after 5 minutes of running water through the hose the numbers were reduced to 8.3×10^2 . This was the exception rather than the rule, as the bacteriological quality of the water from the hose after 5 minutes of running was at all other times less than the standard of 500 organisms/ml (National Research Coun-

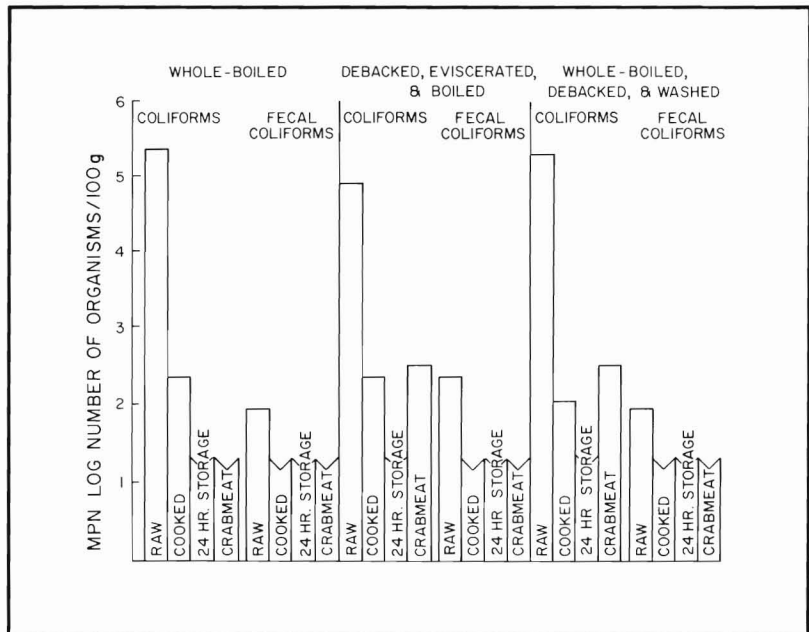


Figure 5.—Coliforms and fecal coliforms for whole-boiled; debacked, eviscerated, and boiled; and whole-boiled, debacked, and washed crabs (v = less than).

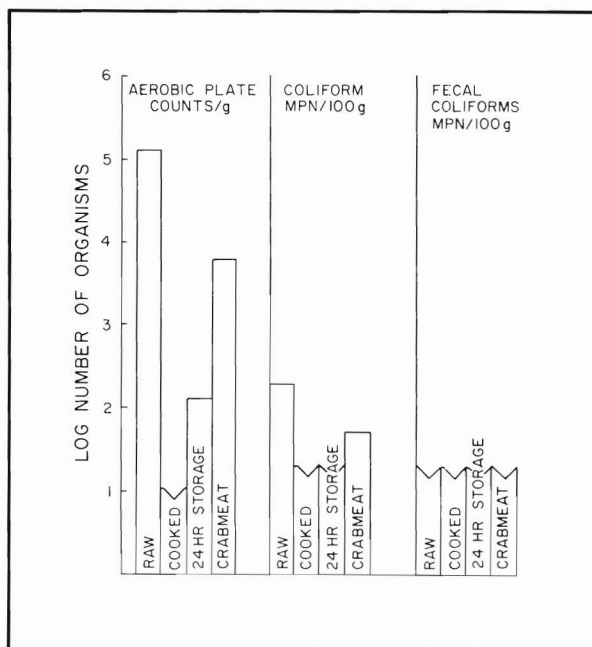


Figure 6.—Aerobic plate count, coliform, and fecal coliform data for whole crabs steamed at 121°C ($v =$ less than).

cil, 1977). Nonetheless, it points out one possible source of contamination, especially if care is not taken to flush the hose after extended periods of nonuse. It is apparent from the APC and coliform data that the extensive handling by the crab picker during meat extraction contributes to the population of these bacteriological indicators. Although the fecal coliform levels were not significantly affected, the data for the APC's and coliforms corroborated work by other investigators (Phillips and Peeler, 1973; Lee and Pfeifer, 1975; Biediger, 1978; and Ward et al., 1976) that human hands contribute significantly to the bacteriological load of picked crab meat.

Representative bacteriological data generated from steaming whole crabs at 121°C for 10 minutes are presented in Figure 6. The bacterial numbers on the raw product are high, as are the bacterial numbers observed on the raw product used in the boiling studies (Fig. 4 and 5). However, the number of viable bacteria remaining on the cooked product is significantly lower. This is, no doubt, due to

the amount of heat processing to which the steamed crabs are subjected.

That steamed crabs produced a cooked product of exceptional bacteriological quality immediately after processing is important, however, just as important are the increases in APC's after 24 hours of storage in a 3.3°C cooler. The increases probably resulted from either post-processing contamination or perhaps repair of injured bacteria. Moreover, the subsequent increases in bacterial numbers on the picked meat are once again evidence of human handling as the primary source of bacterial contamination.

Data obtained for *V. parahaemolyticus*-like organisms or *V. cholerae*-like organisms produced no significant or consistent pattern of isolation. Coagulase-positive isolates of *S. aureus* were obtained from picked meat only once when it was counted at a level of 13,300/g. On every other occasion the same crab picker had been used to minimize variability in meat yield. In this instance, however, the regular

picker was absent and another picker was used. It can be surmised that the regular picker either was not a carrier of *S. aureus* or she practiced very effective sanitary procedures in picking and handling the crab meat. By comparison, the substitute picker may have been a carrier and/or may not have been as cautious in product handling.

The total picked meat yield between the three boiling processes produced no significant differences ($\alpha = 0.05$). However, when meat types (backfin, flake, and claw) were compared, a significant yield difference was detected. The "whole-boiled" flake meat produced a significantly higher yield than did the flake meat produced by "debacking, eviscerating, and boiling" or by "whole-boiling, debacking, and washing". The reason for this phenomenon can possibly be explained on the basis of moisture content (Table 1).

Table 1.—Moisture content of boiled crabs as affected by process and storage.

Process	Percent moisture after process	Percent moisture after 24 hours at 3.3°C
Whole-boiled	82.0	80.9
Debacked, eviscerated, and boiled	82.4	77.6
Whole-boiled, debacked, eviscerated, and washed	82.6	79.0

Apparently, the shell, which remains on the "whole-boiled" crab, acts as an effective barrier to excessive desiccation of the crab while in storage. Furthermore, since this study indicated that flake meat from "whole-boiled" and steamed crabs produced a higher yield than did the flake meat from the other two boiling processes, it should be noted that the area from which the flake meat is picked has the highest degree of exposure on the debacked and eviscerated crabs, thus further contributing to the moisture loss from those areas.

We observed several differences between the data from the steam cooked crabs vs. those obtained from the various boiling processes. For instance,

“whole-boiled” crabs yielded significantly more total meat than did steamed crabs ($\alpha = 0.05$); however, no significant differences were observed in total meat yield when steamed crabs were compared with “debacked, eviscerated, and boiled” crabs and with “whole-boiled, debacked, and washed” crabs. Additionally, the “whole-boiled” backfin produced a significantly greater yield than did steamed crabs. Conversely, steamed crabs yielded significantly more flake meat than the “debacked, eviscerated, and boiled” crabs.

Summary

The method used to process blue crabs does not appear to significantly impact the quality of the picked meat under the conditions which currently prevail in most processing plants. However, it is apparent that steaming crabs under pressure produces an initial cooked product which is bacteriologically superior to those produced by boiling. Nonetheless, since most crab meat is hand picked, any process designed to improve the bacteriological character of the product will be no better than the personal hygiene of the crab picker.

Processing of “debacked, eviscerated, and boiled” crabs does offer the possibility of shortening the cooking

time of these crabs by as much as 35 percent over that of “whole-boiled” crabs, hence saving energy for the processor. Furthermore, although not quantitated in this research, energy can also be saved in the cooling of debacked crabs during refrigerated storage. However, the savings generated in cooking debacked crabs may be effectively lost due to the reduced flake meat yield of the crabs held overnight in refrigerated storage.

These findings are important for many in the crab industry who are processing crabs by whole boiling, then debacking, washing, and refrigerating overnight, insofar as they may be losing yield without the countering benefit of energy savings. To realize the highest picked-meat yield, this study demonstrated the “whole-boiled” crabs with the shells remaining intact during refrigeration prior to picking resulted in the highest yield, because the shell helped protect the meat surfaces from excessive desiccation.

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