

FEASIBILITY STUDY FOR PACKAGING AND PASTEURIZING
MEAT OF THE BLUE CRAB, CALLINECTES SAPIDUS, IN RETORT POUCHES

by

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ABSTRACT

I. INTRODUCTION

It is possible to market crabmeat as freshly picked, frozen, or canned and pasteurized. However, storage limitations exist with the fresh and frozen product. Fresh crabmeat is highly perishable and is rendered unusable by its normal bacterial flora after 7 to 12 days of refrigerated storage (Cockey and Tatro, 1974). Frozen crabmeat has a storage life of only a few weeks due to undesirable changes occurring during this time. The texture of the crabmeat become dry, tough and stringy; flavor becomes flat and off-odors develop (Banks et al., 1977).

The crabmeat industry has relied on pasteurization as a means of extending shelf life of crabmeat because of the above-mentioned limitations. The pasteurization process has given the crabmeat industry flexibility to inventory the product in times of abundance. Therefore, customer demand can be supported during the season when harvest is low. Also, pasteurization has brought price stability to the industry because the processor is not forced to reduce the price of crabmeat during peak harvest seasons.

Pasteurization of crabmeat in conventional cans has been quite successful. Pasteurization destroys most spoilage organisms, thereby extending shelf life under refrigerated storage conditions (Dickerson and Berry, 1974). According to Tatro (1970), pasteurized crabmeat should have a shelf life of 6 months when stored at 32 to 36°F (0.0 to 2.2°C).

A potential alternative method to pasteurization in cans is past-

eurization in retort pouches. The retort pouch is an innovative packaging concept introduced in the 1950's. Retort pouches provide many advantages over conventional cans, such as decreased processing time, lower energy costs, lower unit cost of pouches as compared to cans, reduced transportation costs and better overall product quality (Mermelstein, 1978).

There has been a trend in the crab industry to use cans smaller than the commonly used 401 x 301 (454.0g) cans due to increasing product cost. The use of smaller cans has created a problem in terms of processing requirements. Minimum time - temperature processing requirements have only been established for crabmeat packaged in 401 x 301 cans. Heat penetration experiments need to be conducted with all containers (retort pouches or cans) different than the 401 x 301 can. Process lethality for each container can then be calculated. With this information, process schedules could be adjusted for different size containers to insure an adequately pasteurized product.

If retort pouch pasteurization of crabmeat is found feasible, the crabmeat industry will greatly benefit. Decreased processing time will reduce energy costs and product quality will be better. Therefore, the purpose of this investigation was to compare retort pouches to cans for packaging and pasteurizing crabmeat considering:

1. Container size
2. Heat penetration and heat penetration parameters (f_h , f_c , j_h and j_c)

3. Process lethality
4. The microbiological flora of fresh and pasteurized crabmeat stored at 36°F (2.2°C).
5. The organoleptic quality of pasteurized crabmeat stored at 36°F (2.2°C).

II. REVIEW OF LITERATURE

A. Blue Crab Industry

The blue crab (Callinectes sapidus) industry of the United States is concentrated primarily in Maryland, Virginia and Florida. One of the heaviest concentrations of blue crab is in the Chesapeake Bay where almost 67.1 million pounds are taken annually (Hatem, 1980). In fact, Maryland, Virginia and Florida produce about 70% of the entire United States' catch (Banks et al., 1977).

Blue crabs inhabit shallow waters where harvesting is done by use of trot lines, baited crab pots, scrapes, and dredges. When crabs are delivered to the processor, they are placed in a retort or water bath and given a preliminary cook. Preliminary cooking denatures the meat so it can be more easily removed from the shell and reduces the number of bacteria present in the crab (Tatro, 1970). Cooking in retorts is usually conducted at 250°F (121° C) for 3 to 20 min and water bath cooking at 212°F (100°C) for 15 to 20 min (Banks et al., 1977). The meat is removed from the cooked crabs by hand or mechanical pickers after the crabs have cooled. The crabmeat is then packed in containers and sold as fresh, frozen, or canned and pasteurized.

B. Thermal Processing

Inactivation of bacteria by heat is a fundamental operation in food preservation. Several basic concepts must be understood for a thermal process to be adequate. D values reflect the relative resistance of

spores or vegetative cells to a specific temperature. By definition, D is the time required at a specific temperature to destroy 90% of the spores or vegetative cells of a given organism. The value is numerically equal to the number of minutes required for the survivor curve to transverse one log cycle. The survivor curve is a semilogarithmic plot of survivors versus time at a specific temperature (Stumbo, 1973).

A semilogarithmic relationship between destruction time and temperature was shown by Bigelow (1921). He plotted the first thermal death time (TDT) curve. Thermal death time is the time necessary to destroy a given number of organisms at a specific temperature.

Ball (1923, 1928), in developing the mathematical methods used for calculation of processes for canned foods, pointed out that thermal death time curves of Bigelow (1921) could be characterized by a point and slope. The reference point chosen was the time required to destroy an organism at 250°F (121°C), designated F_0 . The slope of the curve was designated z .

F and z values have an important role in thermal process design. F is the equivalent time, in minutes, at some given reference temperature, of all lethal heat in a process with respect to the destruction of an organism characterized by a given z value (Stumbo, 1973). The z value refers to the number of degrees F required for the thermal death time curve to transverse one log cycle. A z value reflects the relative resistance of an organism to different temperatures and allows for calculation of equivalent thermal processes at different temperatures (Stumbo, 1973).

Application of thermocouples to temperature measurement during thermal processing of foods was an important discovery. This method of measuring temperature, combined with information related to heat resistance of food spoilage bacteria, led to the development of graphical and mathematical procedures for estimating the amount of heat processing required to produce "commercially sterile" and adequately pasteurized food products (Stumbo, 1973).

The first systematic approach to thermal process evaluation was made by Bigelow et al. (1920) and is known as the "General Method" or "Graphical Method". The graphical method integrates the lethal effects of various time - temperature combinations that occur during processing. Values obtained by thermocouple measurement are plotted to give heating and cooling curves. Each temperature, represented by a point on the curve, is considered to have a sterilizing or lethal value. The sterilizing or lethal value of each temperature is numerically equal to the reciprocal of the number of minutes required to destroy some given percentage of organisms at this temperature. Lethality curves are obtained by plotting time and corresponding lethal rates (Stumbo, 1973).

Ball (1923) derived an analytical or "Formula Method" of evaluating processes, "in order to reduce the time necessary to obtain results, as well as to obtain a basis for coordinating the various factors which enter into the calculation". This method employs mathematical equations and accompanying tables which simplify process evaluation. Processing

times and sterilization values are calculated using heating medium temperature, ratio of food product heating rate to sterilization value and differences in temperature between retort and food container at the slowest heating point when steam is shut off.

Several investigators have attempted to simplify the "General Method" and the "Formula Method" for evaluating processes. Olson and Stevans (1939) simplified Ball's "Formula Method" by introducing the "Nomographic Method" of evaluating processes. This method is applicable to canned foods exhibiting straight line semilogarithmic heating curves.

Contributions by Ball (1928), and Schultz and Olson (1940) resulted in an improved "General Method". The primary contribution by Ball (1928) was the construction of a hypothetical thermal death time curve passing through 1 min at 250°F (121°C). Schultz and Olson (1940) improved the "General Method" by employing special coordinate paper designed to simplify calculations. They also introduced formulas for converting heat penetration data from one initial food or retort temperature to another.

A simplified procedure for thermal process evaluation was introduced by Patashnik (1953). This procedure does not involve plotting a curve. Process values can be obtained when temperature readings are taken at equal time intervals during heat penetration testing. This is accomplished by calculating the lethality value for each equal-time-temperature reading. The product of the sum of the lethality values gives the process value directly. This "improved" general method or accumulative lethality method is the most accurate method possible (Stumbo, 1973).

Tabular methods of analysis have been described (Ball and Olson, 1957; Hicks, 1958; Pflug, 1968) for calculating sterilizing values. Parameters necessary in calculations are given in tables.

A review of mathematical procedures for determining sterilization processes was made by Hayakawa (1978). The procedures were divided into groups I and II. Group I procedures were based on the evaluation of lethality at the slowest heating point in food. Group II procedures utilized the mass average lethality of the entire container. According to evaluation, procedures of the two groups produce similar results. However, since Group I procedures require less calculation, he recommended they be used to determine heat processes. Group II procedures are recommended for estimating nutritional or organoleptic quality, because Group I procedures give information on the survival concentration at only one location in the food.

Methods of determining sterilization values have been subject to criticism and revision. Spinak (1981) made a comparison of the general and Ball formula method for retort pouch process calculation. Also investigated was the use of assumed instead of actual values when determining process time by Ball's method. Ball's processing assumptions used in calculations include: exclusion of come-up time lethality, heating slope and cooling slope are equal ($f_h = f_c$) and cooling lag factor (j_c) = 1.41 (Merson et al., 1978). Underestimations of process lethality often result when these assumptions are used. Spinak (1981) found inclusion of come-up time lethality in Ball's method of process cal-

culations reduced the difference in process time between the Ball and general method by 60% (5 min). Inclusion of the actual cooling lag factor was found to reduce the difference in process time by 18% (2 min). Results of the study indicate Ball's formula method merits the use of retort come-up time lethality and the actual cooling lag factor. No significant advantage was gained by using the actual cooling slope.

A procedure for converting an F value determined on the basis of a z_1 value to an F value based on a z_2 value was described and demonstrated by Pflug and Christensen (1980). The conversion process is based on equations. The authors state that F value conversions can not be made unless heating data in the form of time - temperature data or parameters f_h , f_c and j_c are available.

Clostridium botulinum is the organism of primary concern in the low-acid canned food industry because it represents a serious potential health hazard. An adequate thermal process is therefore imperative to insure a safe product. Unfortunately, one of the potential causes of botulism outbreaks in commercially canned foods is an inadequate thermal process.

Esty and Meyer (1922) were responsible for the first systematic investigation of the relationships between C. botulinum spore resistance and temperature in Sorenson's pH phosphate buffer. The "ideal" thermal death time slope of $z = 18$ was established for spores for C. botulinum suspended in phosphate buffer. A semilogarithmic thermal death time curve was constructed from the data by Townsend et al. (1938). The curve

was used as a basis for calculating minimum processes for low-acid canned food. It was found that C. botulinum spores are unable to withstand a heat treatment of 2.78 min at 250°F (121°C) based on a $z = 18$. The classical 250°F (121°C) resistance at 2.78 min is conventionally treated as a minimum value. A longer heat treatment is usually given as protection from other contaminating spores more heat resistant than C. botulinum. The use of an "Fo value", which assumes a $z = 18$, to define low-acid process lethality is nearly universal (Townsend et al., 1968; Stumbo, 1973).

Some indication exists in the literature that the classical resistance value $z = 18$ of C. botulinum spores heated in phosphate buffer is not representative of its resistance when heated in other media. Townsend et al. (1938) found the z value of C. botulinum to be consistently lower in foods ($z = 13.4$ to 15.6) than in phosphate buffer ($z = 18$).

Perkins et al. (1975) determined D values of C. botulinum in formulated combinations of low-acid ingredients to see if they deviated from those in phosphate buffer. Experimental evidence indicated that Fo calculations based on resistance in buffer substantially overstated the lethality during conduction heating processes because cold spots present in foods that heat by conduction are neglected.

Perkins et al. (1975) pointed out that the lower the z value, the more pronounced the effect of slight underprocessing on process lethality, especially at lower temperatures. Above the reference temperature, however, it is possible that the steepest curves could give an over-

estimate of lethality and caution must be used in evaluating temperatures higher than those required (Perkins et al., (1975)).

Perkins et al. (1975) conclude that if the F_0 concept is to continue in its present wide use, values greater than 2.78 min (Townsend et al., 1938) must, in many cases, be considered in order to establish safe and adequate processes. A more realistic estimate of the hazard potential in cans of an underprocessed product can be made if the assumption is made that any contaminating anaerobes have a z value of 14 (Perkins et al., 1975).

A review of F and z values used to ensure the safety of low-acid canned foods was made by Pflug and Odlaug (1978). They conclude, an F_{250} value of 3.0 min using a z value of 18°F has been the minimum botulinum cook standard for more than 40 years and there is no epidemiological evidence to show that this standard has failed.

Pflug and Odlaug (1978) also examined the relationship of z value to D and F value of C. botulinum spores from published data (Esty and Meyer, 1922; Townsend et al., 1938; Reed et al., 1951). The authors report that there appears to be a relationship where large D values at 250°F (121°C) are associated with large z values and small D values at 250°F (121°C) are associated with small z values. F_{250} values versus z values for C. botulinum spores were also examined from a graph published by Townsend et al. (1938). The data showed a trend for the z value to increase with increasing F_{250} values. Based on examination of all data, it was found that large D_{250} values tend to have z values of 18 to 21° F and small

D_{250} values tend to have z values of 13 to 15°F.

Dickerson and Berry (1974) conducted temperature profiles during commercial pasteurization of meat from the blue crab. Lethality of the process used in Virginia was estimated to be equivalent to 18 min at 180°F (82.2°C), based on a z value of 14. This is above the time required to destroy 10^5 to 10^6 spores of C. botulinum type E as shown by Lynt et al. (1977) who found it required less than 13 min.

Thermal death time of C. botulinum type E spores in crabmeat was determined by Lynt et al. (1977) to evaluate the safety of the pasteurization procedure. Thermal death time experiments were conducted at 165°F (73.9°C), 170°F (76.7°C), 175°F (79.4°C), 180°F (82.2°C) and 185°F (85°C) by the TDT tube method. Five strains were studied (Beluga, Alaska, Crab G21-5, Crab 25V-1 and Crab 25V-2). It was found the Buluga and Crab G21-5 strains had z values of 15.2 and the Alaska strain had a z value of 13. Differences in D values at the temperatures studied were small. The Buluga strain had a D_{180} of 0.74 min; Alaska, 0.15 min; Crab G21-5, 0.63 min; Crab 25V-1, 0.62 min; and Crab 25V-2, 0.49 min. The author's findings indicate pasteurization can produce a safe product with regard to C. botulinum type E. These results are in general agreement with Cocky and Tatro (1974). However, Lynt et al. (1977) conclude 1 min at 185°F (85°C) does not appear to be adequate to destroy all spores of C. botulinum type E in crabmeat based on the D_{185} value of 0.29 min for the Beluga strain. The D curves indicate that 3.0 min would provide a 12D process for the most resistant strain, but the TDT curve for the same

strain suggests that such a process would require 10 min. The conclusions made by Lynt et al. (1977) concerning time of processing at 185°F (85°C) appear to be inaccurate since pasteurization at 185°F (85°C) for 1 min does not result in a process lethality equal to 1. Lynt et al. (1977) apparently neglected to consider come-up and come-down time lethality that occurs when cans are pasteurized at 185°F (85°C) for 1 min. Furthermore, when pasteurization is followed by refrigeration at 46°F (7.8°C) or below, the surviving spores will not grow and produce toxin in crabmeat (Solomon et al., 1977).

Preliminary cooking processes on whole crabs was investigated by Dickerson and Berry (1976) to determine if C. botulinum spores would survive the process. Lethal effects of retort and water bath processes were determined using a z value of 14. The z value of C. botulinum type E spores in fish paste is 14 as determined by Angelotti (1970). The estimated thermal process in the retort had a lethality equivalent to 4 min at 200°F (93.3°C). Lethality of the water bath process was estimated to be equivalent to 11 min at 200°F (93.3°C). Estimated lethality of the water bath method had the higher lethality because of the longer time of process.

Lynt et al. (1979) studied heat resistance of strains 190, 202, and 610 of nonproteolytic C. botulinum type F in phosphate buffer. Strain 202 was also studied in crabmeat. Thermal death time was calculated by the test tube method at 160°F (71.1°C), 165°F (73.0°C), 170°F (76.7°C), 180°F (82.2°C) and 185°F (85°C). In phosphate buffer (pH 7.0), thermal

death time curves indicated strain 190 had a z value of 10.25, strain 202 had a z value of 10.40 and strain 610 had a z value of 14.75. The z value obtained in crabmeat for strain 202 was 13.50, representing an increase in z of 3.10. There was a longer destruction time for type F spores in crabmeat at all temperatures studied. z values calculated from D curves were 9.75 for strain 190, 9.50 for strain 202, 11.30 for strain 610 and 11.50 for strain 202 in crabmeat. In phosphate buffer, D values ranged from 31.08 min at 160°F (71.1°C) to 0.25 min at 180°F (82.2°C) for strain 190, 42.41 min at 160°F (71.1°C) to 0.33 min at 180°F (82.2°C) for strain 202 and 6.64 min at 170°F (76.7°C) to 0.37 min at 185°F (85°C) for strain 610. In crabmeat, D values for strain 202 ranged from 9.50 min at 170°F (76.7°C) to 0.53 min at 185°F (85°C), compared to 4.29 min at 170°F (76.7°C) to 0.33 min at 180°F (82.2°C) in buffer. This suggests crabmeat offers protection to spores of strain 202.

Lynt et al. (1979) concluded that spores of nonproteolytic C. botulinum type F are similar in heat resistance to type E except that the slopes of TDT and D curves of type F are steeper and heat resistance is generally greater in the temperature range studied.

In a similar study, Lynt et al. (1981) examined the heat resistance of proteolytic C. botulinum type F strains Langeland, 4YRC and PC in phosphate buffer. Strain 4YRC was also studied in crabmeat. Thermal death time were conducted at 210°F (98.9°C), 215°F (101.7°C), 220°F (104.4°C), 225°F (107.2°C) and 230°F (110°C) by the TDT tube method. In phosphate buffer, TDT curves indicated the Langeland strain had a z value

of 22.1, the PC strain had a z value of 20.0 and the 4YRC strain had a z value of 21.1. D curves indicated the Langeland, PC and 4YRC strains had z values of 19.1, 18.1, and 25.3, respectively. Strain 4YRC's D curve from crabmeat indicated z value of 23.0 compared to a z value of 25.3 in phosphate buffer. D values, in phosphate buffer, ranged from 23.22 min at 210°F (98.9°C) to 1.82 min at 230°F (110°C) for strain PC, 19.38 min at 210°F (98.9°C) to 1.79 min at 230°F (110°C) for strain Langeland, and 12.14 min at 210°F (98.9°C) to 1.45 min at 230°F (110°C) for strain 4YRC. In crabmeat, strain 4YRC had D values ranging from 5.07 min at 215°F (101.7°C) to 1.35 min at 230°F (110°C), compared to 5.35 min at 215°F (101.7°C) to 1.45 min at 230°F (110°C) in buffer. Therefore, it appears crabmeat has little effect on heat resistance of strain 4YRC. The authors conclude that thermal processes adequate to destroy proteolytic C. botulinum types A and B would also destroy type F because the heat resistance values obtained for type F are in the expected range for type A and proteolytic type B.

C. Pasteurization of Crabmeat

Fresh crabmeat is a perishable product. Therefore, it has a limited shelf life. Freezing as a means for extending shelf life has not been successful for the blue crab. Because of these limitations the industry has relied on pasteurization as a means of extending shelf life of crabmeat. Pasteurization destroys the most troublesome spoilage organisms found in crabmeat and extends shelf life to about 6 months under refrigerated storage conditions (Lynt et al., 1977).

Pasteurization of crabmeat in 1 lb metal containers was first investigated by Tobin and McClesky (1941b). Pasteurization processes at 250°F (121°C) for 5, 10, and 15 min were examined as a means of destroying Escherichia coli and reducing total bacterial counts. The 15 min pasteurization process reduced total bacterial counts to a small fraction of the original number, and E. coli was absent. Processing for 5 and 10 min did not satisfactorily reduce total bacterial counts or eliminate E. coli.

Fellers and Harris (1940) were the first to successfully use the canning process to obtain a commercially sterile product. Success was achieved by carefully selecting good quality crabs, improving handling methods, using dipping salt brines (aluminum sulfate) to prevent gray discoloration, and applying heat treatments sufficient to kill microorganisms without cooking.

Water bath pasteurization of crabmeat packed in tin plate cans was first investigated by Anzulovic and Reedy (1942). The crabmeat was packaged in No. 2 tin plate cans. The authors found that crabmeat pasteurized to temperatures of 145°F (62.8°C) for 30 min, 160°F (71°C) for 10 min and 170°F (76.7°C) for 1 min was free from E. coli. Pasteurized crabmeat stored at 41 to 43°F (5 to 6°C) for as long as 5 weeks was also free from E. coli.

Pasteurization studies on crabmeat were conducted by Littleford (1957). Processing to an internal temperature of 170°F (76.7°C) for 1 min was determined adequate for pasteurization of crabmeat.

Flynn and Tatro (1966) studied the effects of pasteurizing 454.0g of crabmeat packed in 307 x 400 containers at 185°F (85°C) and 190°F (87.8°C). Bacteriological examination indicated crabmeat should be processed at a minimum time-temperature relationship of 185°F (85°C) for 110 min which complies with the pasteurizing recommendation of the Maryland State Department of Health. When this process was used, no spoilage was detected during 6 months storage at 33 to 35°F (0.6 to 1.7°C).

An examination of pasteurizing procedures was made by Tatro (1970). Referring to Littleford's (1957) pasteurization procedure Tatro (1970) found that processing to an internal temperature of 170°F (76.7°C) for 1 min was not sufficient to insure desired refrigerated shelf life for meat having high bacterial loads. Tatro found a minimum pasteurization treatment of 185°F (85°C) for 1 min at the internal critical point in crabmeat, followed by immediate cooling in an ice water bath to less than 100°F (37.8°C) and refrigerated storage at 32 to 36°F (0 to 2.2°C) was necessary to insure an adequately pasteurized product.

The Tri-State Seafood Committee (1969) recommends that crabmeat should be pasteurized until the geometric center of the container reaches 185°F (85°C) and is held at that temperature for 1 min. Also recommended is immediate cooling to 100°F (37.8°C) in less than 50 min and subsequent refrigeration at 32 to 36°F (0 to 2.2°C).

Lerke and Farber (1971) pasteurized Dungeness crabmeat in Mylar pouches at 180°F (82.2°C) for 1 min. Staphylococcus and Salmonella introduced into these packages were destroyed at inoculum levels of 10^7 and

10^8 cells/g. Pasteurization processes at 180°F (82.2°C) for 5 min allowed some spores of C. botulinum type E to survive when packages were inoculated with 10^3 spores. Storage at 40°F (4.4°C) prevented growth of Staphylococcus and Salmonella but not C. botulinum. It was concluded that for complete safety, a storage temperature of 36°F (2.2°C) would be required following pasteurization.

Survival rates of C. botulinum type E in pasteurized meat of the blue crab were investigated by Cockey and Tatro (1974). They found the recommended minimum pasteurization process of 1 min at 185°F (85°C) internal meat temperature and subsequent storage at 40°F (4.4°C) reduced type E spore levels in inoculated packs of crabmeat from 10^8 spores/100 g to 6 or less spores/100 g. The pasteurized meat remained nontoxic during 6 months of storage at 40°F (4.4°C).

A comparison of crabmeat pasteurization processes was made by Dickerson and Berry (1974). Plants in Florida, South Carolina, North Carolina, Virginia and Maryland were surveyed. They found that water bath temperatures used in the 5 commercial plants were reasonably constant, ranging from 186 to 189°F (85.6 to 87.2°C). Holding times in the water baths were variable, ranging from 92 to 150 min. The authors concluded that thermal death time data are needed to evaluate the lethal effect of each process.

A concern of processors is the uneven distribution of heat in a can of large size. This could result in reduced product quality because high temperatures tend to darken or discolor meat close to the can walls.

Because of this concern, Dickerson and Berry (1974) conducted temperature profiles across a single can by installing 4 thermocouples along the radius of the can. They found considerable differences in the amount of heat received by meat at the inside can surface and center of the can. The temperature of meat $\frac{1}{4}$ in away from the can wall was above 184°F (84.4°C) for 41 min, but the temperature of meat at the center of the can was above 184°F (84.4°C) for only 6 min. They suggest to simply use smaller cans. "If the shortest dimension between the geometric center and wall of the can is reduced by a factor of 2, heating and cooling times will be reduced by a factor of 4, since heating and cooling rates vary as the square of thickness" (Dickerson and Read, 1973).

D. Microbiology of Fresh and Pasteurized Crabmeat

Many bacteriological studies have been undertaken to identify the bacterial flora of crabmeat. The bacterial flora of freshly caught crab should reflect the water from which they are taken. Contamination usually occurs from decks the crabs are thrown on, handlers, washing waters and pickers (Jay, 1978).

A study of crabs and crabmeat by Harris (1932) concluded that decomposition is due primarily to organisms of Proteus, Pseudomonas and Flavobacterium groups. Harris also found that during the early stages of crabmeat spoilage, E. coli was present when stored at 68°F (20°C) but almost absent when stored at 36 to 41°F (2 to 5°C).

Tobin et al. (1941) examined iced, fresh crabmeat packed in 1 lb snap-lock cans stored at 33.8 to 41°F (1 to 5°C) with initial counts of

1×10^5 to 3×10^6 bacteria/g. Bacteria isolated at time of storage were primarily cocci, although some Bacillus, Achromobacter, Flavobacterium, Alcaligenes, Escherichia and Pseudomonas were present. Total counts increased steadily during storage. After a week, gram negative rods, primarily Pseudomonas and Achromobacter became dominant.

The presence of E. coli in crabmeat is considered to be evidence of unsanitary conditions in production or handling of the meat. During the past four decades, the Food and Drug Administration has been taking regulatory action against firms producing crabmeat under unsanitary conditions when the observed conditions were substantiated by the presence of indicator organisms such as E. coli (Phillips and Peeler, 1972).

Tobin and McClesky (1941a) examined fresh and iced crabmeat to determine the bacterial condition of the meat and incidence of E. coli. Initial studies indicated E. coli was not detected in either live or steamed crabs. Initial counts ranged from 1×10^5 to 3×10^6 bacteria/g in live crabs and 1.5×10^4 to 5×10^5 bacteria/g in steamed crabs. Following picking however, bacteriological examination indicated E. coli was present in many samples.

In a similar study, Tobin and McClesky (1941b) found that a large number of fresh crabmeat samples were contaminated with E. coli. E. coli per gram (MPN) meat was found to exceed 1 in 63% and 10 in 20% of the samples tested. Total counts varied from 8.7×10^4 to 1.6×10^7 /g meat.

Search for the source or sources of contamination in both studies by

Tobin and McClesky (1941a, 1941b) indicated that the presence of E. coli in crabmeat was due to hands of employees, dipping brines, and ice used for cooling the brine and keeping barrels of meat cool. Thus, use of E. coli as an index of unsanitary conditions appears to be justified since coliform organisms associated with crabs are destroyed by adequate steaming prior to picking the meat (Tobin and McClesky, 1941b).

Survival time of coliform bacteria and enterococci in iced crabmeat was investigated by McClesky and Boyd (1949). Initial aerobic counts ranged between 2.6×10^5 and 1×10^7 bacteria/g. Spoilage was obvious after 9-13 days storage at which time aerobic counts were usually over 1×10^9 bacteria/g. Coliform bacteria increased during iced meat storage, while enterococci remained unchanged. When spoilage occurred, there was an increase in enterococci. E. coli, as indicated in a limited number of tests, persisted throughout the storage period, but did not significantly increase. The authors found no relationship between initial total counts or enterococci and coliform bacteria.

Sterilized crabmeat has been inoculated with a variety of microorganisms to determine what will grow if the crabmeat is intentionally contaminated. Berry (1942) inoculated cultures of E. coli, Proteus, sp., Salmonella aerotrycke, Salmonella morgani, Salmonella typhosa, Shigella dysenteriae, and Staphylococcus aureus into sterilized crabmeat and observed growth rates. Significant increases in bacterial plate counts were noted with each culture when incubated at 77° (25°C) or 99°F (37°C). Total bacterial counts decreased at 41°F (5°C). However, viable organ-

isms were still present after 15 days storage at this temperature.

A common organism found in oceanic and coastal water is Vibrio parahaemolyticus. Seafoods such as oysters, shrimp and crab serve as vehicle foods for V. parahaemolyticus (Jay, 1978). Because food poisoning from this organism is a possibility, Fishbein et al., (1970) serologically tested (slide agglutination) 60 samples of processed blue crab (unpasteurized) from the Chesapeake Bay for the presence of V. parahaemolyticus. Positive test results were observed in 56 of these samples.

In 1971, V. parahaemolyticus was implicated in an outbreak of gastroenteritis from the consumption of blue crabmeat. The organism was isolated from 2 steamed crabs that were served at a picnic. The crabs were supplied by a crab house in Chesapeake Bay, Maryland (USPHS, 1971).

Phillips and Peeler (1972) conducted an extensive bacteriological survey of the blue crab industry. They found plants operating with good sanitary conditions had bacterial counts significantly lower than those plants operating with poor sanitary conditions. Average counts from sanitary plants indicated coliform organisms less than 20/g (MPN), no E. coli and coagulase-positive Staphylococcus less than 30/g (MPN) in 93% of the plants surveyed. Total aerobic counts were less than 1×10^5 in 93% of the plants surveyed with counts from 85% of those below 5×10^4 /g.

Bacteriological spoilage characteristics of a canned, pasteurized crab cake mix product stored at 86°F (30°C), 64°F (18°C) and 36°F (2°C) was investigated by Loaharanu and Lopez (1970). The product was packaged

in 1 lb cans (307 x 409) and pasteurized at 185°F (85°C) for 110 min and immediately cooled. A large number of bacteria survived pasteurization even though counts were reduced by a factor of approximately 20.

Bacillus and Micrococcus were the predominant organisms isolated during storage at 86°F (30°C) and 64°F (18°C). Alcaligenes predominated at 36°F (2°C). E. coli was absent from the product.

Ward et al. (1977) investigated the anaerobic microflora of unpasteurized and pasteurized crabmeat. The predominant microorganisms isolated, by strict anaerobic techniques, were Lactobacillus. The author concluded that if some lactobacilli survive pasteurization, they may contribute to spoilage of the canned product.

C. botulinum has been found in the marine environment inhabited by the crab and in the blue crab itself. Ward et al. (1967a) made an intense survey of the United States Gulf Coast to determine the presence or absence of C. botulinum types A, B, C, D and E. Soil and animal samples were taken during summer and winter months. During the winter months, 3 samples of blue crab were taken from Shell Beach, LA and examined for the presence of C. botulinum. One of the samples contained C. botulinum type D. No other types were observed.

In a similar study, Ward et al. (1967b), examined the United States Atlantic Coast and estuaries from Key Largo to Staten Island for the presence of C. botulinum. Botulinum-positive crabs were absent in this study.

Williams-Walls (1968) isolated two proteolytic strains of C.

botulinum type F from crabs in the York River located in Virginia. According to the author, "This is the first time proteolytic strains of this type have been isolated in the United States and the first demonstration of the presence of type F on the eastern coast of the United States."

Cockey and Tatro (1974) investigated the incidence of C. botulinum type E in the Chesapeake Bay area. C. botulinum growth and toxin production in crabmeat homogenates were also studied. Mud samples, taken from areas where crabs were harvested, indicated type E spores were present in 21 out of 24 samples. Sterilized crabmeat homogenates, when inoculated with as little as 5 type E spores/10g, became toxic when incubated at 50°F (10°C), 75°F (24°C) and 85°F (29.4°C). Growth and toxin production at 40°F (4.4°C) required inocula levels of 10^3 spores/10g crab homogenates.

Kautter et al. (1974) investigated the incidence of C. botulinum in fresh and pasteurized crabmeat. It was found that out of 986 samples of fresh crabmeat tested, 4 contained C. botulinum type E and 2 contained proteolytic type B. One thousand samples of pasteurized crabmeat were examined and 1 sample contained a proteolytic strain of type F. Spores of this strain were found to be too heat resistant for the pasteurization process to destroy.

In a similar study, Lerke and Farber (1971) examined pasteurized Dungeness crabmeat for the presence of C. botulinum. C. botulinum was not isolated from the 74 samples tested. However, it was found that

Dungeness crabmeat is a suitable substrate for C. botulinum growth. Pasteurization for 5 min at 180°F (82°C) did not destroy all spores of C. botulinum type E based on an inoculum level of 10^3 spores/mylar-polyethylene pouch containing 170.3g of crabmeat. Toxin formation by type E occurred at 40°F (4.4°C) after 30 to 40 days storage. Because toxin formation of C. botulinum type E occurred at 40°F (4.4°C), Lerke and Farber (1971) concluded that, "For complete safety a holding temperature of 36°F (2.2°C) or lower at all times would be required, but that it could not be expected to be maintained in commercial channels."

The effect of incubation at 34° F (1.1°C), 36°F (2.2°C) and 38°F (3.3°C) on growth and toxin production of C. botulinum type E, inoculated into sterilized beef stew, was examined by Schmidt et al. (1961). Results indicated toxin production at 38°F (3.3°C) in the substrate but not at 34°F (1.1°C) or 36°F or 2.2°C) during 104 days storage. Extended storage at 38°F (3.3°C) is not safe with respect to outgrowth and toxin production by C. botulinum type E. These results are in agreement with Lerke and Farber (1971).

Solomon et al. (1977) also investigated the effect of low storage temperatures on growth of nonproteolytic C. botulinum type E spores and proteolytic C. botulinum type B and F spores in meat of the blue crab. Storage temperatures studied were 39°F (4°C), 47°F (8°C), 54°F (12°C) and 79°F (26°C). Sterilized crabmeat was inoculated with unheated (10^3 spores/g) and heated (10^4 spores/g) spores and incubated under anaerobic conditions. All spore types grew and produced toxin in crabmeat stored

at 79°F (26°C) - unheated spores in 3 days and heated spores in 6 days. Unheated type E spores grew and produced toxin in crabmeat at 54°F (12°C) in 14 days but not at any lower storage temperature within 180 days. Neither heated type E spores nor heated and unheated spores types B and F grew in crabmeat at 39°F (4°C), 47°F (8°C) or 54°F (12°C) within 180 days. The authors conclude the pasteurization schedules in the crab industry are adequate to destroy spores of nonproteolytic type E strains but not proteolytic strains of type B and F. However, proteolytic strains of type B and F do not grow in crabmeat under refrigerated storage conditions of 39 to 47°F (4 to 8°C).

E. Retort Pouch

The retort pouch might be the most revolutionary development in the food packaging industry since the tin can. It has been called a unique package in a class of its own (Peters, 1976). The retort pouch earned the Institute of Food Technologists' 1978 Food Technology Industrial Achievement Award for the United States Army Natick Research and Development Command, Continental Flexible Packaging - A Member of The Continental Group, Inc. (formerly Continental Can Co.) and the Flexible Packaging Division of Reynolds Metals Co. (Mermelstein, 1978).

In 1959, the United States military investigated the idea of a retort pouch as an alternative package for its combat rations. Scientists at the Army Research and Development Laboratory at Natick, Massachusetts were looking for a package that would be lighter than the conventional metal can, could be carried by a soldier without interfering

with normal movement, would fit into combat uniform pockets, and would not hurt the soldier if he fell on it. It should also be durable, easily opened and disposed of. In addition, the military wanted the food to be stable without refrigeration, ready to eat without thawing, be acceptable hot or cold and be equal in quality to canned food (Mermelstein, 1978).

Ten years passed before the development of a material that could withstand sterilizing temperatures of 250°F (121°C). Other problems existed. The Food and Drug Administration (FDA) was dissatisfied with the pouch when it was found that adhesive compounds were migrating into the food. In 1976, the Natick laboratory came up with a modified pouch that satisfied FDA's standards.

In 1958, Continental's Flexible Packaging Division initiated work on retort pouch materials. One year later, sample pouches were tested under simulated retort conditions. Continental's pouch material was used in Natick's first commercial procurement of 40,000 reformed pouches in 1962 (Mermelstein, 1978).

In the mid-1950's, Reynolds' Flexible Packaging Division began working on the retort pouch concept. Two trial runs were made with preformed pouches in the early 1960's (Mermelstein, 1978).

Reynolds' pouch is trademarked "flex-can" and Continental's is called "C-79" (Mermelstein, 1976). Pouches manufactured by both companies consist of a three-ply laminate held together by the adhesive, polyurethane. The three-ply laminate consists of a 0.0127 mm outer layer of polyester which provides toughness, abuse resistance and printability;

a 0.0089 mm middle layer of aluminum foil acts as a barrier to light, moisture, gas and microorganisms; and a 0.0762 mm inner layer of polyolefin which is inert and therefore does not react with food. Polyolefin also provides an extremely strong heat-seal that withstands high pressure and temperature.

Retort pouches offer many advantages over cans. Decreased pouch processing time is perhaps the most significant advantage. Processing time is reduced because it takes less time for the center of the product to reach lethal temperature. According to Llewellyn (1981), it takes 60% more energy to produce, process and package canned foods than foods in the pouch. Kraft food industry reported that with the retort pouch, it has been able to cut its processing time up to 50% compared to canned food processing. Reduction in heat exposure also results in improved food product quality with better taste, color and texture than similar products processed in cans. Potential for nutritional advantages exists as well, particularly where heat-sensitive nutrients are concerned (Heintz, 1980).

Transportation costs are much lower because pouches weigh only a fraction of what cans weigh. "For example, 1000 8 oz steel cans weigh 109 lbs, compared to just over 12 lbs for equivalent pouches" (Heintz, 1980).

According to Llewellyn (1981), taste tests conducted by private companies comparing pouched, frozen and canned foods showed that pouched and frozen foods were indistinguishable in most cases. Canned foods

rated third.

Other advantages of pouched foods include: no need of refrigeration or freezing if the pouched product is commercially sterile; ease of heating; ease of opening; and requires less storage and disposal space.

The major advantage of the retort pouch is lack of high-speed filling equipment. Mermelstein (1976) reported Natick laboratories could fill only 35 pouches/min. This is slow compared to conventional cans and glass jars which are filled at speeds up to 1,200/min and 200 to 400/min, respectively (Mermelstein, 1976). According to Cage and Clark (1980), development of high-speed form/fill/seal machines with running speeds of 250 pouches/min will greatly increase production efficiency. In late 1980, Bartelt Machinery Division of Rexham Company announced development of the first high-speed form/fill/seal machines for retort pouches. This machine is capable of filling pouches in continuous motion at speeds of 250 packages/min (Heintz, 1980).

Reliability of the retort pouch as a suitable replacement container has been questioned. It should have a failure rate no greater than that obtained with cans. Failure rates of one pouch/10,000 or less has been the goal in research. Preliminary tests and large scale pilot work done under contract proved this requirement could be met under production conditions (Tuomy and Young, 1982).

Economic considerations for new product feasibility are extremely important, thus several investigations have been conducted. Steffe et al. (1980) examined energy requirements and costs of retort pouch versus

can packaging systems. The original canning line, an improved canning line and a retort pouch line in the plant were the processing systems considered. Each of the systems were capable of producing 43.3 metric tons of processed spinach /8 hr shift. Comparisons of energy and container needs for each system were made. It was reported that container manufacturing used more than 80% of the total amount of energy required. Pouch processing lines have higher electrical costs, but these costs are small compared to total costs. Differences in processing energy requirements for food production in retort pouches and cans are small. Total energy requirements for retort pouch packaging systems are significantly less than can packaging systems. Thus, the authors conclude that container and energy costs for retort pouch packaging systems are significantly lower than those for comparable can packaging systems.

The economic feasibility of using retort pouches for processing, packaging and distributing processed fruit and vegetable products was examined by Williams et al. (1981). Three packaging systems were considered; an existing canning line, a new canning line and a retort pouch line. The retort pouch packaging system was found to be the overall minimum cost packaging system. Costs associated with machinery for retort pouch processing are high, but lower freight costs, retort pouch costs and the lower amount of energy used in transportation and container manufacture contribute to the cost effectiveness of the pouch packaging system.

Processing retort pouches in conventional can sterilizers was an

economic consideration investigated by Roop and Nelson (1981). A cylindrical rack was designed for the pouch which is identical to dimensions of the No. 10 can. The rack permits pouch processing in traditional sterilizers that accept cans of this size. The investigators found this racking method provides equal heat treatment to all pouches. Thus, pouches can also be processed in conventional can sterilizers.

A "Code of Practice" for retort pouches was formulated by Turtle and Alderson (1971). In the code it is stated that, "Processed pouches must be handled mechanically at all stages up to and including cartoning and overwrapping, and that no manual handling can be allowed during this period." Effects of handling procedures on pre-process and post-process contamination were investigated by Michels and Schram (1979).

Enterobacter aerogenes was used as an indicator organism in the pouches. The authors found rough handling during retort loading increased the number of punctured pouches from 0.06 to 0.27%. The effect of post-process handling procedures on leaker spoilage was also examined using pouches deliberately punctured. When these pouches were cooled in tap water, manually unloaded from the retort and stored wet, the incidence of post-process contamination reached 90%. If the pouches were dried immediately after manual unloading, contamination rates were only 10%. Cooling in chlorinated water as opposed to tap water and drying prior to manual unloading further reduced the contamination rate to less than 1%. Therefore, manual handling of dry pouches as investigated by Michels and Schram (1979) proves to be an acceptable alternative to complete mechan-

ical handling.

Microbiological stability of food processed in flexible pouches was investigated by Rauhala and Clegg (1978). Pouches of small potatoes were inoculated with 5×10^5 spores Bacillus stearothermophilus and processed at 250°F (121°C) for 20 min. Steam retorts modified to allow a water cooking process were used. This treatment destroyed the spores without overcooking the potatoes. To test storage stability, uninoculated potatoes with a natural contamination level of 4×10^3 spores/pouch were processed in a retort at 250°F (121°C) for 17 to 25 min. These potatoes were stored at 86°F (30°C) for 6 months. There was no microbial growth during this time.

The retort pouch is very well established in Europe and Japan, but consumer acceptance for retort pouched food in the United States still needs to be determined. Sensory panels at Natick Laboratory and Swift Research Center determined consumer acceptance ratings of food packaged in retort pouches. Average scores 7.5 and higher (hedonic scale) indicated potentially high levels of consumer acceptance (Duxbury, 1973). Also, retort pouch research was boosted in 1979 when it was announced that the Department of Defense would award contracts totaling approximately 70 million dollars (Bannar, 1979). At the present time, several major food companies, including Kraft, Hormel and ITT Continental Baking are marketing, in selected cities, food products packaged in single-serving-size retort pouches. Most of the foods being offered are entrees, but liquid food products such as sauces and salad dressing have

been undergoing market testing. In the United States armed forces, meat entrees such as beef stew, ham and meatballs are being packaged in retort pouches (Tuomy and Young, 1982).

III. MATERIALS AND METHODS

A. Procurement of Crabmeat

Fresh picked crabmeat was shipped in plastic containers (454.0 g) on ice from a crabmeat processor in Hampton, VA to Blacksburg, VA. Upon arrival the crabmeat was stored at 36°F (2.2°C) until needed.

B. Heat Penetration

The rate of heat penetration was obtained with cans and retort pouches containing 113.5 g, 227.0 g and 454.0 g of fresh picked crabmeat. Enameled tin cans (211 x 114) used for processing 113.5 g of crabmeat were supplied by Blue Channel Corp., Port Royal, SC. Aluminum cans (307 x 206) used for processing 227.0 g of crabmeat were supplied by a Hampton, VA crab processor. Plain tin cans (303 x 406) used for processing 454.0 g of crabmeat were obtained from American Can Co., Waukegan, IL. Tin plate cans (401 x 301) with aluminum lids used for processing 454.0 g of crabmeat were supplied by a Hampton, VA crab processor. Retort pouches used for processing 113.5 g and 227.0 g of crabmeat were 12.7 x 19 cm. Retort pouches used for processing 454.0 g of crabmeat were 17.8 x 22.9 cm. Dimensions (length x width x thickness) of retort pouches filled and sealed with 113.5 g, 227.0 g and 454.0 g of crabmeat were 12.7 x 11.4 x 2.6 cm, 12.7 x 12.6 x 3.4 cm and 17.8 x 14.6 x 4.5 cm, respectively. Retort pouches were a three-ply laminate consisting of an outer layer of polyester, a middle layer of aluminum foil and an inner layer of polypropylene (Reynolds Metals Co., Richmond, VA).

Internal temperatures of crabmeat in cans were measured during processing with rigid type T (copper-constantan) molded bakelite thermocouples (O.F. Ecklund, Cape Coral, FL). Thermocouples were installed with the temperature-sensitive tip located at the geometric center of the can. Thermocouples lengths were 3.3 cm, 4.3 cm, 4.0 and 5.2 cm for the 211 x 114, 307 x 206, 303 x 406 and 401 x 301, respectively. Thermocouples were mounted on cans as described by Alstrand and Ecklund (1952), and Ecklund (1956). Internal temperatures of crabmeat in retort pouches were measured using 24 gauge nylon insulated, copper-constantan thermocouple wire (O.F. Ecklund). Retort pouches were prepared for thermocouple installation by cutting an 8 mm diameter hole in the side seam. Thermocouple wire lengths were inserted into the pouch to the geometric center. Wire lengths were 5.4 cm, 5.4 cm and 7.9 cm for pouches containing 113.5 g, 227.0 g and 454.0 g, of crabmeat, respectively. A stuffing box (O.F. Ecklund) consisting of brass fittings and rubber gaskets was used to seal each thermocouple in the pouch.

Retort pouches and cans were manually filled with the appropriate amount of crabmeat. After filling, the crabmeat was firmly packed into the pouches such that no air pockets remained. The pouches were triple-sealed with a constant heat sealing bar (Clamco Inc.) heated to 375°F (191°C). The cans were mechanically closed (211, 307 and 401 cans: Dixie Can Co. closer, model 23; 303 can: American Can Co., closer, model 423.IES.00).

Eight containers representing each type and size were separately

processed for each determination. Cans were put in baskets and retort pouches were vertically placed into compartments of a wire-mesh rack (30.5 x 21.6 cm).

Pasteurization was carried out in a steam-heated water bath (Chester-Jensen Co., Inc., model 203) preheated to 190°F (87.8°C). Dimensions (length x width x depth) of the water bath were 86.0 x 40.5 x 71.0 cm. Processing was in accordance with procedures outlined by the Tri-State Seafood Committee (1969) on pasteurization of crabmeat. Packaged crabmeat was heated to an internal temperature of 185°F (85°C) for 1 min and immediately cooled in an ice water bath (31°F; 0°C) to less than 50°F (10°C) within 1 hr. Thermocouples inserted in the water bath and at the containers cold-point (geometric center) monitored temperature during heating and cooling. Temperatures were recorded at 1 min intervals (Monitor Labs, Inc., Data Logger, model 9300). This experiment was repeated for reproducibility of results.

Time-temperature data were plotted on rectangular coordinate graph paper for each set of containers. The resulting heating and cooling curves for pouches and cans containing equal amounts of crabmeat were compared for time necessary to reach pasteurization temperature from a starting temperature of 50°F (10°C), time required for cooling to less than 50°F (10°C) and total processing time. Analysis of variance was performed on the data and differences were determined using Duncan's multiple range test (Barr et al., 1976).

C. Heat Penetration Parameters

Time-temperature data for each set of containers were also plotted on three-cycle semilogarithmic graph paper for construction of heating and cooling curves (Appendix I) in order to calculate the parameters f_h , f_c , j_h , and j_c (Appendix II). Data representing the heating portion of each pasteurization process were plotted on inverted semilog paper. With the graph paper oriented this way, the numbers on the right on the log scale represented the difference between water bath temperature and internal container temperature. The top line of the graph paper was labeled one degree below water bath temperature and the temperatures were plotted directly (Stumbo, 1973). To obtain the cooling curve, the difference between internal container temperature and cooling water temperature was plotted on the log scale against time on the linear scale. In this case, the semilog graph paper was kept in its normal position. The bottom line on the graph was labeled one degree above cooling water temperature and the temperatures were plotted directly (Stumbo, 1973).

The parameters f_h and f_c were calculated by locating two temperature points representing a difference of one log cycle and determining the difference of time on the abscissa that corresponds to this difference in temperature (Stumbo, 1973).

The parameters j_h and j_c were calculated by determining the time lag before the heating (cooling) curve assumed a straight line on semilogarithmic paper.

The equation presented by Stumbo (1973) is as follows:

$$j_h (c) = (T_w - T_{pih} (c)) / (T_w - T_{ih} (c))$$

in which $j_h (c)$ = heating (cooling) lag factor.

$T_w (c)$ = temperature of heating (cooling) water bath.

$T_{pih} (c)$ = temperature represented by the extension of the straight-line portion of the semilog heating (cooling) curve.

$T_{ih} (c)$ = product temperature at the time heating (cooling) is started.

Analysis of variance was performed on the parameters and differences were determined using Duncan's procedure (Barr et al., 1976).

D. Process Lethality

Process lethality values were obtained using time-temperature data for containers. Based on the "improved" general method, temperatures were converted to equivalent lethal values and summed together to obtain sterilizing or F values (Patashnik, 1953). A computer program based on Patashnik's (1954) method was used for F value calculation (National Food Processors Association, Washington, D.C.). Sterilizing or F values were determined with the following z values: 8, 10, 12, 13, 14, 15, 16, 17, 18, 20 and 22. Analysis of variance was performed on the F values and differences were determined using Duncan's procedure (Barr et al., 1976).

A crab processor in Hampton, VA pasteurizes crabmeat packed in 307 x 206 cans (227.0 g) instead of the 401 x 301 cans (454.0 g) used to determine recommended minimum levels of pasteurization (Tri-State Seafood

Committee, 1969). Therefore, to insure an adequate process, 307 x 206 cans (227.0 g) are processed until reference 401 x 301 cans (454.0 g) reach an internal meat temperature of 185°F (85°C) for 1 min. A similar heat penetration experiment was conducted to determine the effects of this processing method in terms of total processing time and F value. However, in this experiment 303 x 406 cans (454.0 g) were used because these cans were readily available. Eight 307 x 206 cans containing 227.0 g of crabmeat and 8 303 x 406 cans containing 454.0 g of crabmeat were pasteurized together. All cans were removed from the hot water bath for cooling when the 303 x 406 cans containing 454.0 g of crabmeat reached an internal temperature of 185°F (85°C) for 1 min. Methods of container filling, sealing, pasteurization and F value determination were previously described. Analysis of variance was performed on the data (Barr et al., 1976).

E. Pasteurizing Crabmeat for Storage

Storage stability was determined in terms of microbiological analysis and sensory evaluation with pasteurized crabmeat stored at 36°F (2.2°C). Seventy 211 x 114 cans and 70 retort pouches were filled with 113.5 g of crabmeat and closed as described in the heat penetration study. Prior to filling, the containers were dipped in 0.01% sodium hypochlorite solution.

Retort pouches and cans were pasteurized to an F value equivalent to that obtained with 303 x 406 cans containing 454.0 g of crabmeat because equal processing lethality was desired. F_{185} values based on z values of 16 were used for determining process schedules. A z value of 16 was used

as it was considered to be the value likely found for spore contamination on pasteurized crabmeat. F_{185}^{16} values for 211 x 114 cans (113.5 g), 303 x 406 cans (454.0 g) and retort pouches containing 113.5 g of crabmeat were 12, 24 and 8, respectively, when the product was heated to an internal temperature of 185°F (85°C). In order to achieve an equivalent process, the pouches and cans containing 113.5 g of crabmeat were pasteurized at 185°F (85°C) for an additional 16 and 12 min, respectively, after the product had reached 185°F (85°C) for one min. This represents the difference in F value between containers (pouches and cans) packed with 113.5 g of crabmeat and 303 x 406 cans packed with 454.0 g of crabmeat.

Can and retort pouches were stored at 36°F (2.2°C) following heat processing. Containers remained at this storage temperature for the duration of the 6 month study.

F. Microbiological Analysis of Fresh and Pasteurized Crabmeat

Pasteurized crabmeat stored at 36°F (2.2°C) was used for microbiological analysis. At day 0 and at 2 week intervals, thereafter, for 6 months, 3 sample 211 x 114 cans (113.5 g) and 3 sample retort pouches (113.5 g) were removed from storage (36°F; 2.2°C) and analyzed for mesophilic aerobes, mesophilic anaerobes, psychrotrophic aerobes, psychrotrophic anaerobes and lactobacilli.

Samples were initially diluted by adding 2.0 g of crabmeat to 18 ml sterile 0.1% (w/v) Bacto-peptone dilution blanks and mixed by shaking. Subsequent serial dilutions were made with the initial 1:10 dilution in

sterile 0.1% (w/v) Bacto-peptone dilution blanks.

Mesophilic and psychrotrophic organisms were estimated using duplicate pour plates of Trypticase Soy Agar (TSA; Baltimore Biological Laboratories, BBL; Cockeysville, MD). Mesophilic aerobic and anaerobic plates were incubated at 95°F (35°C) for 48 hr. Psychrotrophic aerobic and anaerobic plates were incubated at 70°F (21°C) for 48 hr.

Anaerobiosis was achieved by incubating plates in GasPak anaerobic jars (BBL, Division of Becton-Dickenson and Co., Cockeysville, MD) with GasPak H₂ + CO₂ generator envelopes (BBL, Division of Becton-Dickenson and Co., Cockeysville, MD).

Lactobacilli were estimated using duplicate pour plates of lactobacilli MRS broth (MRS, Difco) containing 0.18% agar (BBL). Plates were poured with an overlay (10 ml) and incubated at 70°F (21°C) for 72 hr.

G. Sensory Evaluation

Crabmeat used for sensory evaluation was packaged and pasteurized as described in the section on pasteurizing crabmeat for storage.

The purpose of the taste panel was to compare retort pouch and can pasteurized crabmeat in terms of flavor, color, texture, odor and overall acceptability. Crabmeat packaged in cans and pouches was evaluated at 1, 4, 8, 12, 16, 20, and 24 weeks storage at 36°F (2.2°C).

An affective sensory test method (IFT, 1981) was used by the panel judges to rate sample preference and acceptability. The type of affective test chosen was the hedonic rating scale. Samples were rated on a nine point scale; a score of 1 indicated "extremely unacceptable" and a score

of 9 indicated "extremely acceptable". The taste panel evaluation form is in Appendix II.

A ten member taste panel evaluated the crabmeat. Panel judges were staff members and graduate students in the Department of Food Science and Technology (VPI & SU) who were trained in taste panel methods.

A taste testing laboratory with partitioned booths served as the test location. Samples were served under fluorescent white lights. Crabmeat samples were served in duplicate and randomized on paper plates. The samples were identified by letters. Approximately 25.0 g/sample were served each judge. A cup of water was served to each judge to rinse their mouth between samples.

The experimental design was a two-way factorial analysis of variance. The two factors in the design - treatment and judges - were fixed (Model 1). Analysis of variance was performed on the taste panel (Barr et al., 1976).

IV. RESULTS AND DISCUSSION

A. Heat Penetration

There has been a trend in the crab industry to utilize cans smaller than commonly used 401 x 301 cans (454.0 g). This is due to increasing product cost. Unfortunately, minimum time-temperature recommendations for pasteurization have only been established for crabmeat packaged in 401 x 301 cans (454.0 g). It is recommended that these cans (401 x 301) should be processed to 185°F for 1 min for adequate pasteurization (Tri-State Seafood Committee, 1969). The lack of specific processing requirements has created a problem in establishing pasteurization schedules. For example, 307 x 206 cans containing 227.0 g of crabmeat are currently marketed and this container has no specific requirements for pasteurization. Also, new types and sizes of containers might conceivably be used for pasteurizing crabmeat. The retort pouch is such a container. The geometry and packaging material of the retort pouch accounts for a heating and cooling rate that is more rapid than a can. Therefore, it is extremely important that specific processing requirements should be established for containers exhibiting various heating and cooling characteristics.

As a first step in determining processing requirements, heat penetration studies were conducted with containers currently used and some types of containers that might eventually be used. Typical heating and cooling curves for retort pouches and cans containing 454.0 g, 227.0 g and

113.5 g of crabmeat are given in Figures 1, 2 and 3. Only data from one experimental run is given, because the two separate experiments in this study produced similar results. Data in each graph represent the average thermocouple reading of eight containers. Heating times given for pouches and cans are based on a common starting temperature of 50°F (10°C). Retort pouches, 303 x 406 cans and 401 x 301 cans containing 454.0 g of crabmeat required 80 min, 88 min and 95 min, respectively, for the geometric center of the containers to reach 185°F (85°C), the desired temperature for pasteurization (Fig. 1). Ice water cooling from 185°F (85°C) to less than 50°F (10°C) required 56 min, 81 min and 104 min, respectively. Both come-up and cooling times of retort pouches were significantly less ($P \geq 0.05$) than the 303 x 406 cans and 401 x 301 cans. Total processing times were 137 min, 170 min and 201 min for retort pouches, 303 x 406 cans and 401 x 301 cans, respectively. A 32% reduction in processing time existed between retort pouches and 401 x 301 cans which are currently being used to pasteurize crabmeat.

The heating data for the 401 x 301 cans (454.0 g) most commonly used to pasteurize crabmeat compares favorably with that reported by Littleford (1957) and Dickerson and Berry (1974). Littleford (1957) and Dickerson and Berry (1974) found it required 65 and 62 min, respectively, for the centers of 401 x 301 cans (454.0 g) to reach 170°F (76.7°C). In this study, 401 x 301 cans (454.0 g) required approximately 59 min to reach 170°F (76.7°C) (Fig. 1).

Pasteurization temperature (185°F; 85°C) was reached in 42 min and

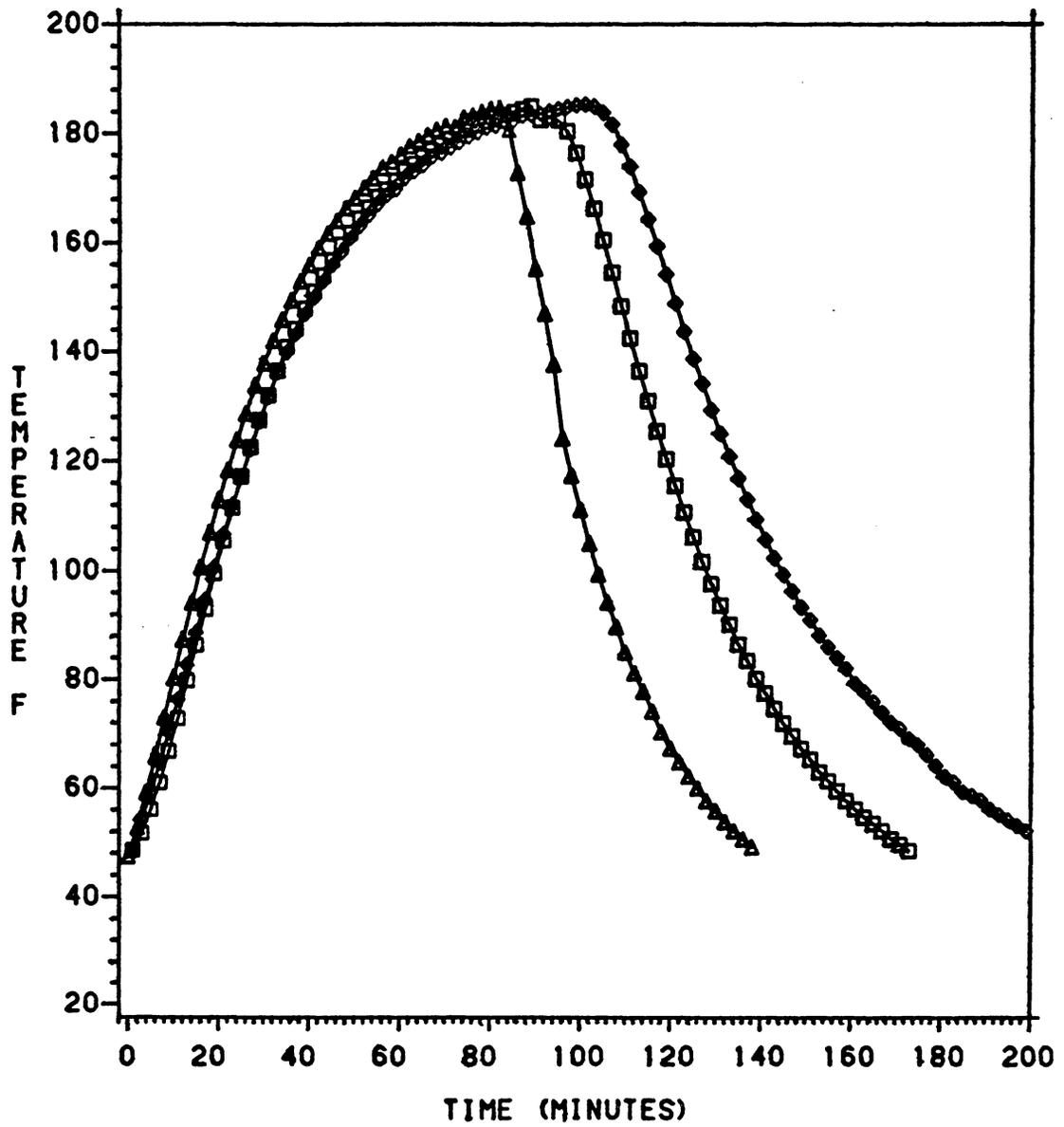


Figure 1. Heating and cooling curves for retort pouches (Δ), 303 x 406 cans (\square) and 401 x 301 cans (\diamond) containing 454.0 g of crabmeat pasteurized to 185 °F (85 °C) for 1 min.

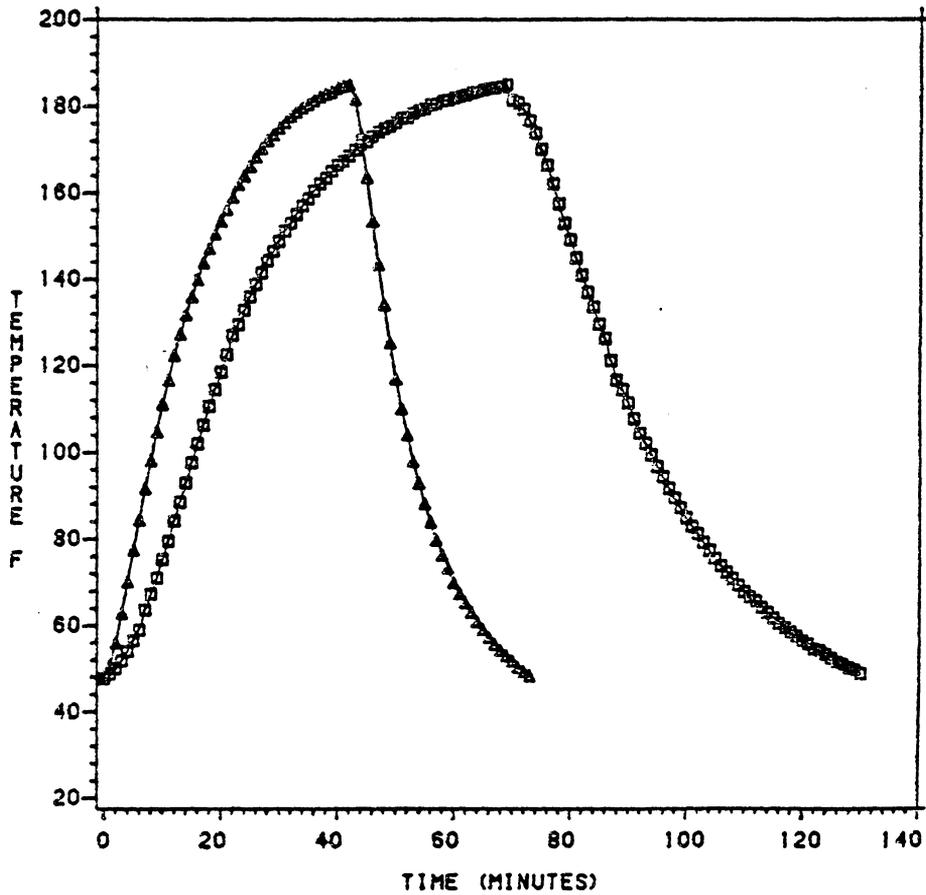


Figure 2. Heating and cooling curves for retort pouches (Δ) and 307 x 206 cans (\square) containing 227.0 g of crabmeat pasteurized to 185 °F (85 °C) for 1 min.

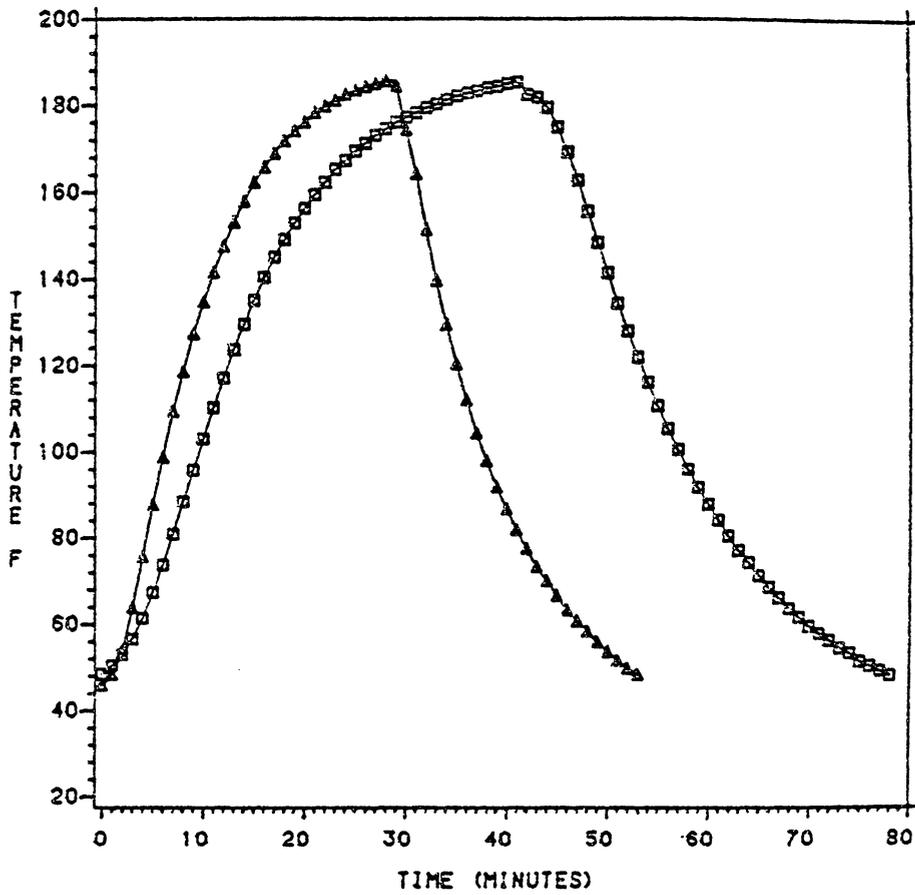


Figure 3. Heating and cooling curves for retort pouches (Δ) and 211 x 114 cans (\square) containing 113.5 g of crabmeat pasteurized to 185 °F (85 °C) for 1 min.

68 min for retort pouches and cans (307 x 206), respectively, packed with 227.0 g of crabmeat (Fig. 2). Retort pouches required 29 min and cans required 60 min for cooling to less than 50°F (10°C). Heating and cooling times of retort pouches were significantly less ($P \geq 0.05$) than cans. The total processing times of 72 min and 129 min for retort pouches and cans, respectively, were significantly different ($P \geq 0.05$). This corresponds to a 45% reduction in processing time for the pouch.

Retort pouches and cans (211 x 114) containing 113.5 g of crabmeat required 27 min and 42 min, respectively, to reach 185°F (85°C) (Fig. 3). Retort pouches required 23 min and cans required 36 min for cooling to less than 50°F (10°C). Heating and cooling times of retort pouches were significantly less ($P \geq 0.05$) than cans. The total processing times of 51 min and 79 min for retort pouches and cans, respectively, were significantly different ($P \geq 0.05$). This corresponds to a 36% reduction in processing time for the retort pouch.

The significantly lower ($P \geq 0.05$) heating, cooling and total processing time of retort pouches containing 454.0 g, 227.0 g and 113.5 g of crabmeat were expected. Thinner profiles and increased surface area of retort pouches permits rapid heating and cooling. Therefore, processing time should be less in retort pouches than cans packed with the same amount of crabmeat.

Decreased processing time is a major advantage of the retort pouch. Heintz (1980) reported that Kraft Food industry has been able to cut its processing time up to 50% when using the retort pouch instead of the can.

Reduction in heat exposure would also result in improved food product quality with better taste, color and texture than similar products processed in cans. Potential for less nutrient destruction exists as well (Heintz, 1980).

Economic considerations of retort pouch feasibility have also been considered. Steffe et al. (1980) and Williams et al. (1980) considered energy requirements and costs of retort pouch versus can packaging systems. In both studies it was found that container and energy costs for retort pouch packaging systems are significantly lower than those for comparable can packaging systems. Thus, utilization of retort pouches for packaging and processing crabmeat would be a feasible alternative method of pasteurization. However, the pasteurization process currently recommended (Tri-State Seafood Committee, 1969) for the 401 x 301 can may not be adequate for the pouch since the overall pasteurization process depends upon the lethality of the process and not necessarily attaining a temperature of 185°F (85°C) for 1 min. For this reason it is important that each containers heating and cooling characteristics be analyzed and the process lethality calculated.

B. Heat Penetration Parameters

In order to better compare heating and cooling characteristics of retort pouches and cans packed with the same amount of crabmeat, semi-logarithmic heat penetration graphs (Appendix I) were constructed with the parameters f_h , f_c , j_h and j_c (Appendix II) calculated as described in Materials and Methods. This method of plotting data greatly increases

the amount of information which can be derived from the data. Results are presented in Table 1.

The parameter f is the reciprocal of the slope of the heating (f_h) and cooling (f_c) curve. The values obtained for f_h and f_c were significantly lower ($P \geq 0.05$) for retort pouches than cans of equal crabmeat content. The calculated f_h value of retort pouches packed with 113.5 g of crabmeat was 34% lower than 211 x 114 cans (113.5 g). Pouches packed with 227.0 g of crabmeat had an f_h value that was 39% lower than 307 x 206 cans (227.0 g). Pouches packed with 454.0 g of crabmeat had an f_h value that was 7% lower than 303 x 406 cans (454.0 g) and 17% lower than 401 x 301 cans (454.0 g). The calculated f_c value of retort pouches packed with 113.5 g of crabmeat was 37% lower than 211 x 114 cans (113.5 g). Pouches packed with 227.0 g of crabmeat had an f_c value that was 52% lower than 307 x 206 cans (227.0 g). Pouches packed with 454.0 g of crabmeat had an f_c value that was 25% lower than 303 x 406 cans (454.0 g) and 39% lower than 401 x 301 cans (454.0 g). The fact that retort pouches had f_h and f_c values significantly lower ($P = 0.05$) than cans packed with the same amount of crabmeat was expected because the pouches had faster heating and cooling rates (Appendix I). According to Ball and Olson (1957), f is dependent on the kind of material being heated, and is independent of the thermocouple position and initial food product being heated. In this study, the parameter f was dependent on the specific size and shape of the container.

The parameter j is referred to as the lag factor since it is a

Table 1: Heat penetration parameters for retort pouches and cans containing 454.0 g, 227.0 g and 113.5 g of crabmeat and pasteurized to 185°F (85°C) for 1 min.^{1,2}

Parameters ³	454.0 g			227.0 g		113.5 g	
	I ⁴	II	III	I	IV	I	V
f_h	51.5a	55.5b	62.0c	25.5a	42.3b	16.7a	16.0b
f_c	56.7a	75.6b	93.0c	27.6a	59.0b	24.6a	34.5b
j_h	1.4a	1.5a	1.5a	1.5a	1.5a	1.5a	1.6a
j_c	1.1a	1.4b	1.3b	1.0a	1.2b	1.0a	1.2b

¹ Values are the mean of 1 - 8 replicate determination.

² Values in the same row for each packing size with different lower case letters are significantly different ($P \geq 0.05$).

³ Values of parameters are given in min.

⁴ Roman numerals refer to: I - retort pouches, II - 303 x 406 cans, III - 401 x 301 cans, IV - 307 x 206 cans and V - 211 x 114 cans.

The parameter j is referred to as the lag factor since it is a measure of the lag in establishing a uniform heating rate. The parameter j is dependent on the initial temperature distribution, thermocouple position of the food product being heated and ratio of can length to can diameter (Ball and Olson, 1957). Heating lag factors (j_h) were generally the same (no significant differences) for retort pouches and cans containing the same amount of crabmeat. In fact, heating lag factors (j_h) were generally the same for all containers, regardless of type and size. A long lag for retort pouches was unexpected but could have been due to the swelling experienced by the pouches immediately after being immersed in the hot water bath. This would account for the extended lag in heating. However, retort pouch cooling lag factors (j_c) were significantly less ($P \geq 0.05$) than cans with equal amounts of crabmeat, because thin profiles and increased surface area of retort pouches permits rapid cooling.

C. Process Lethality

The Patashnik (1953), or accumulative lethality, method was used for determining F values in this study. The reason for this was two-fold. First, it is the most accurate method possible (Stumbo, 1973); and second, Ball (1923) makes several assumptions in his formula method that often result in underestimates of process lethality. One assumption is that $f_c = f_h$. Making this invalid assumption often results in underestimates of lethality accumulated during the cooling period of the process (Hayakawa, 1978). Parameters f_c and f_h calculated for each set

the cooling lag factor (j_c) equals 1.41. Results presented in Table 1 indicate this assumption is not accurate. Ball (1923) chose $j_c = 1.41$ for mathematical convenience. Since most cooling curves do not have the assumed j_c value of 1.41, some error exists in process sterilization or F values estimated by Ball's method (Hayakawa, 1978). According to Hayakawa (1978), Ball's method overestimates F values when actual cooling lag factors (j_c) are less than 1.41 and underestimates F values when actual cooling lag factors are greater than 1.41.

F values calculated by Patashnik's (1953) method are presented in Fig. 4. Since F values are dependent on z , comparisons of process lethality must be based on F_{185} values calculated with the same z value.

All containers, representing type and size were processed to 185°F (85°C) for 1 min in accordance with the procedure recommended for 401 x 301 cans (454.0 g) (Tri-State Seafood Committee, 1969). The resulting process lethalties (F_{185} values) of the containers were different due to variations in container geometry, volume and packaging material.

Retort pouches had F_{185} values that were significantly less ($P \geq 0.05$) than cans containing equal amounts of crabmeat. This was attributed to the geometry and packaging material of the retort pouch which are conducive to heating and cooling rates more rapid than cans. As a result, retort pouches passed through the lethal temperature range faster with less accumulated lethality (F value).

There is no mention of z value in the Tri-State Seafood Committee's (1969) recommended pasteurization process. Actually, no problem would

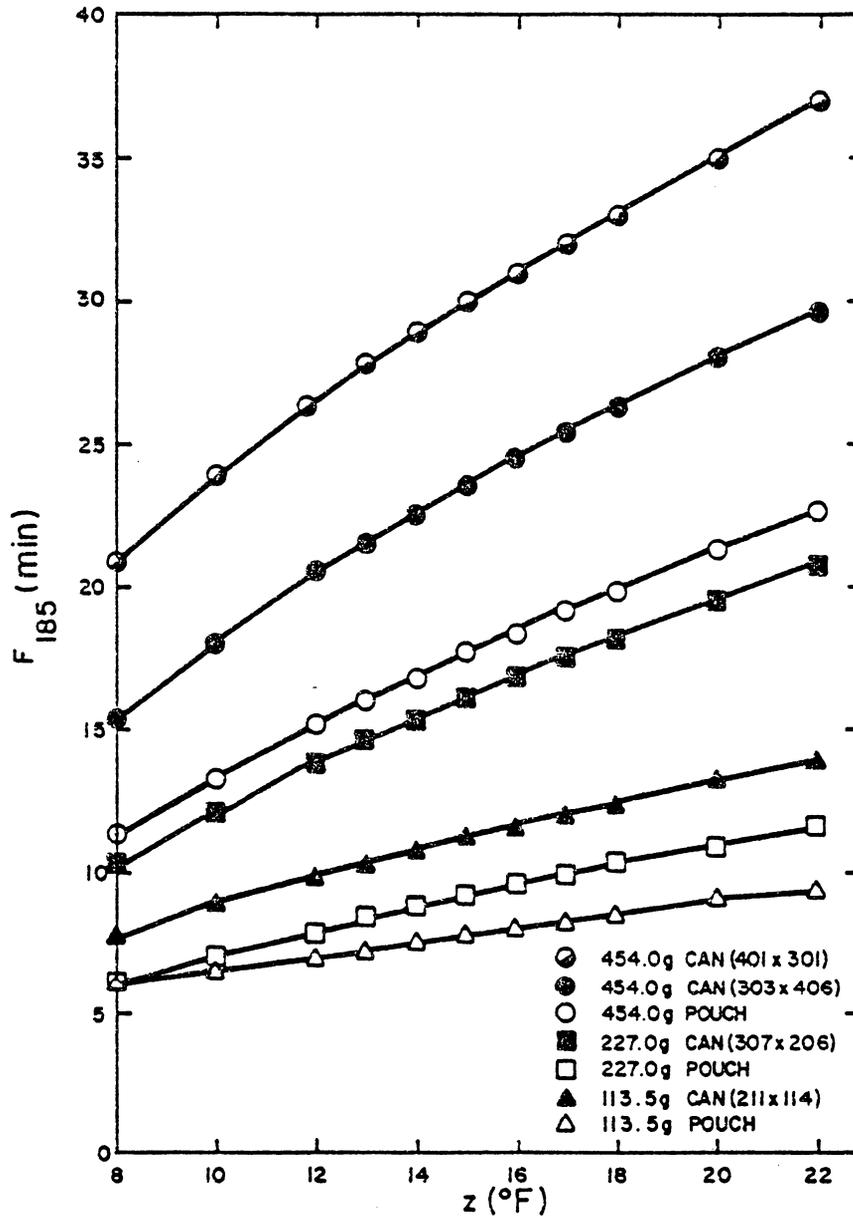


Figure 4. F values for containers pasteurized to 185 °F (85 °C) for 1 min and subsequently cooled to less than 50 °F (10 °C).

exist if standard 401 x 301 cans containing 454.0 g of crabmeat were pasteurized, since the actual amount of heat a standard can receives is the same, assuming each can heats and cools at the same rate. The problem arises when one wants to pasteurize containers other than standard cans. This problem was encountered when I wanted to pasteurize retort pouches and cans containing 113.5 g of crabmeat. A z value representative of the types of organisms of concern had to be established before an equivalent process could be given. The z value gives an indication of the heat resistance of an organism to different temperatures. Processes designed to adequately pasteurize or sterilize a product based on the z value of a particular organism may not be adequate to destroy an organism with a different z value. The choice of a z value has a direct influence on process lethality (Fig 4). For example, if a process were designed to destroy organisms with a z value of 8, it would not be adequate to destroy organisms with a z value of 22 based on the overall process lethality given in Fig. 4. The z value chosen depends on the organism one is trying to destroy. A z value of 8-12 is representative of most non-sporing bacteria, yeasts and molds; 13-14 of C. botulinum type E; and 18-20 of C. botulinum types A and B (Stumbo, 1973). Therefore, it is important that the appropriate z value be chosen so processing schedules can be safely established.

C. botulinum has been demonstrated in the blue crab (Ward et al., 1967a, b; Williams-Walls, 1968; Lilly et al., 1971; Cockey and Tatro, 1974) and in pasteurized crabmeat (Kautter et al., 1974). Therefore, a z

value appropriate for this organism was chosen. Under ordinary circumstances, the containers packed with 113.5 g of crabmeat would have been pasteurized to an equivalent F value of 401 x 301 cans. However, these cans (401 x 301) were not readily available. Therefore, equivalent processes based on the F value of 303 x 406 cans (454.0 g) calculated with a z value of 16 were given to retort pouches and 211 x 114 cans (113.5 g) that were pasteurized for storage at 36°F (2.2°C).

The calculated F_{185}^{16} values for retort pouches and cans containing 113.5 g of crabmeat were 8 and 12, respectively. The F_{185}^{16} value was 24 for 303 x 406 cans containing 454.0 g of crabmeat. Therefore, retort pouches and cans were pasteurized at 185°F (85°C) for an additional 16 and 12 min, respectively, to obtain an equivalent process ($F_{185}^{16} = 24$). If the containers packed with 113.5 g of crabmeat had been pasteurized to an equivalent F_{185}^{16} value of 401 x 301 cans, retort pouches and cans would have been pasteurized at 185°F (85°C) for an additional 23 and 19 min, respectively, since the F_{185}^{16} value of 401 x 301 cans is 31. This method of obtaining equivalent processes is shorter than other methods used for obtaining equivalent processes. For example, one could process the retort pouches and cans packed with 113.5 crabmeat until reference 303 x 406 cans reached pasteurization temperature, but this would add more than the 16 or 12 min that are necessary to achieve an equivalent process. Calculations similar to the ones discussed can also be made for containers of different size and with different amounts of product.

Retort pouches equivalent to cans can be easily and rapidly obtained.

However, the specific F and z values must be known to give a microbiologically adequate process. Advantages of knowing the required F value are further exemplified in the following discussion:

A crab processor in Hampton, VA pasteurizes packed crabmeat in 307 x 206 cans containing 227.0 g of product. Pastuerization at 185°F (85°C) for 1 min is the standard procedure for 401 x 301 cans containing 454.0 g of crabmeat. Therefore, to insure an adequate process, 307 x 206 cans containing 227.0 g of crabmeat are processed until reference 401 x 301 cans containing 454.0 g of crabmeat reach 185°F (85°C) for 1 min. Containers are subsequently cooled. Although this method of pastuerizing 307 x 206 cans (227.0 g) insures an adequately pasteurized product, the actual lethal effects of processing are undoubtedly much greater than 401 x 301 cans containing 454.0 g meat.

In this study, a similar experiment was conducted except 303 x 406 cans (454.0 g) instead of 401 x 301 (454.0 g) were used. Trends resulting from the experiment will be the same however. The containers were prepared as described in Materials and Methods. As shown in Fig. 5, the 307 x 206 cans (227.0 g) reach pasteurization temperature at a faster rate, therefore, the actual length of time that these cans remain at 185°F (85°C) is greater than 1 min. Consequently, total process lethality in the smaller container is significantly greater than that of the larger can ($P \geq 0.05$). F_{185}^{16} values of containers pasteurized by this method are 38 and 24, for 307 x 206 cans and 303 x 406 cans containing 227.0 g and 454.0 g of crabmeat, respectively (Table 2). This

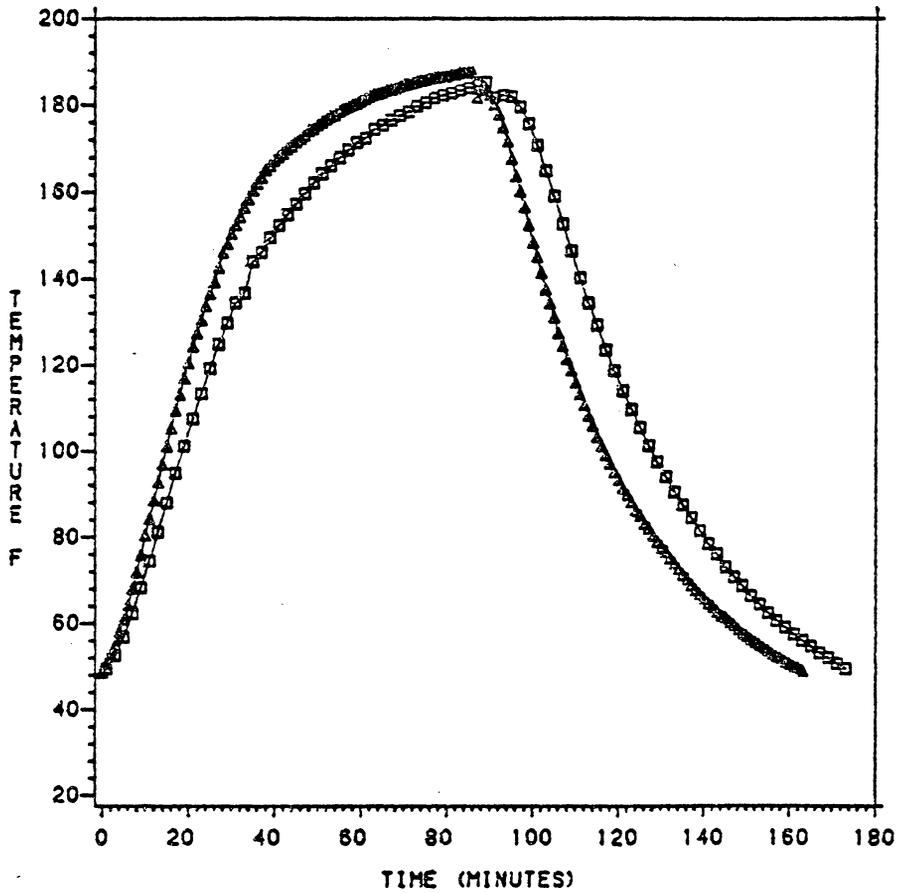


Figure 5. Heating and cooling curves for 307 x 206 cans (Δ) containing 227.0 g of crabmeat and 303 x 406 cans (\square) containing 454.0 g of crabmeat. The 307 x 206 cans were pasteurized until reference 303 x 406 cans reached an internal meat temperature of 185 °F (85 °C) for 1 min.

Table 2: F values of 307 x 206 cans (227.0 g) and 303 x 406 cans (454.0 g) pastuerized until reference 454.0 g cans reached 185°F (85°C) for 1 min^{1,2}

F_{185} Values ³		
z values	307 x 206 cans (227.0 g)	303 x 406 cans (454.0 g)
8	36a	15b
10	36a	17b
12	36a	20b
13	37a	21b
14	37a	22b
15	38a	23b
16	38a	24b
17	39a	25b
18	39a	26b
20	40a	27b
22	41a	29b

¹ Values are the mean of 2 - 8 replicate determinations

² Values in the same row with different lower case letters are significantly different ($P \geq 0.05$).

³ F_{185}^{16} Values are given in min.

corresponds to an unnecessary F value increase of 14 for the smaller container. In addition, total processing time for both containers is approximately 172 min, much greater than is necessary to achieve an equivalent process. One can determine the necessary conditions for adequately pasteurizing crabmeat packed in 307 x 206 cans (227.0 g) by referring back to Fig. 4. F_{185}^{16} values are 17 and 24 for 307 x 206 cans and 303 x 406 cans containing 227.0 g and 454.0 g of crabmeat, respectively. Therefore, 307 x 206 cans containing 227.0 g of crabmeat require an additional 7 min at 185°F (85°C) for an equivalent process based on the F_{185}^{16} value of 303 x 406 cans containing 454.0 g of crabmeat. As a result, total processing time would be 137 min (i.e., 67 min heating to 185°F (85°C), 1 min plus 7 min additional at 185°F (85°C) and 62 min cooling) instead of 172 min. Therefore, pasteurizing these containers to equivalent F values would be considerably more efficient. Pasteurizing the crabmeat in retort pouches instead of cans would require even less processing time. This would further reduce energy costs and product quality would be better.

Very little information regarding process lethality of pasteurized crabmeat has been published. Dickerson and Berry (1974) evaluated the lethality of the crabmeat pasteurization process in Virginia to be equivalent to an $F_{180}^{14} = 18$ for a 401 x 301 can (454.0 g). Lynt et al. (1977) reported that this is considerably above the time required to destroy $10^5 - 10^6$ spores of the most heat resistant strain of C. botulinum type E. They found the most heat resistant strain would be

destroyed in less than 13 min. "Moreover, when D_{180} is considered, it is also well above a 12D process with respect to type E, since D_{180} for the most resistant strain is less than one" (Lynt et al. 1977). For crabmeat pasteurization processes at 185°F (85°C) for 1 min, Lynt et al. (1977) reported that these processes do not appear adequate to destroy all spores of C. botulinum type E. This statement appears to be inaccurate since pasteurization at 185°F (85°C) for 1 min does not result in a process lethality equal to 1. Only if instantaneous heating and cooling occurred would process lethality equal 1. Lynt et al. (1977) apparently neglected to consider come-up and come-down time lethality that occurs when cans are pasteurized at 185°F (85°C) for 1 min. When all lethal heat is considered, process lethality of 303 x 406 cans (454.0 g) based on a z value of 16 is 24 min. This is well above the time necessary for a 12 D reduction of C. botulinum type E based on the D_{185} value (0.29) min reported by Lynt et al. (1977). In fact, based on an F_{185}^{16} value of 24 and a D value of 0.29, this corresponds to an 82 D reduction.

In summary, retort pouch total processing time and consequently the parameters f_h and f_c were significantly less ($P \geq 0.05$) than cans containing equal amounts of crabmeat. This is probably the most important advantage of retort pouch processing. Decreased processing time would mean lower energy costs to the industry. In addition, reduced product exposure to heat would result in better overall product quality.

Also, by evaluating thermal process found adequate to achieve the desired degree of product sterilization in terms of F and z value,

procedures for applying equivalent processes can be easily calculated.

D. Microbiological Analysis of Fresh and Pasteurized Crabmeat

Microbiological counts of crabmeat packaged in retort pouches and cans were estimated before and after pasteurization. The purpose of this was to determine the adequacy of pasteurizing both types of containers to an equivalent F_{185}^{16} value of 24.

Crabmeat pasteurized in cans has an expected shelf life of 6 months when stored at 32 to 36°F (0.0 to 2.2°C) (Tatro, 1970). However, an expected refrigerated shelf life of crabmeat packaged and pasteurized in retort pouches does not exist. Therefore, microbial loads were estimated for pasteurized crabmeat packed in both types of containers at 2 week intervals during 6 months storage at 36°F (2.2°C). Resulting microbial counts would provide information concerning the feasibility of using retort pouches as an alternative or replacement container.

Total aerobic counts of fresh crabmeat obtained in this study were 5.3×10^5 /g (Table 3). This count slightly exceeded the limit of 10^5 /g for fresh crabmeat suggested by Elliot and Michener (1961) and Jay (1978). According to Tatro (1970), the Standard Plate Count (SPC) of whole crabs should not exceed 10^5 bacteria/g following cooking and cooling if acceptable, fresh quality meat is to be packed. In this study, the crabmeat was 2 days old by the time the initial dilutions were prepared. Thus, growth during this time could account for increased bacterial numbers. Total bacterial counts of fresh crabmeat exceeding the limit of 1×10^5 /g were also found by Phillips and Peeler (1972) when

they conducted a bacteriological survey of the blue crab industry. Initial counts for mesophilic anaerobes, psychrotrophics aerobes, psychrotrophic anaerobes and lactobacilli are given in Table 3.

Psychrotrophic counts of the fresh crabmeat were about 1 log cycle higher than mesophilic counts (Table 3). This was expected because organisms commonly associated with crabmeat are psychrotrophic.

Initial aerobic and anaerobic mesophilic counts of crabmeat were almost identical (Table 3). This suggests that the organisms which grew were the same and, therefore, facultative in nature. This trend was also apparent for the aerobic and anaerobic psychrotrophic counts (Table 3), suggesting facultative organisms.

The initial psychrotrophic anaerobic counts of crabmeat obtained in this study were in the same range (10^6 to 10^7 organisms/g) obtained by Ward et al. (1977). However, both the initial psychrotrophic aerobic counts and lactobacilli counts obtained in this study were about 1 log cycle higher than Ward et al. (1977). Ward et al. (1977) obtained counts of 1×10^4 and 3.4×10^3 organisms/g for psychrotrophic aerobes and lactobacilli, respectively.

Immediately following pasteurization, enumeration of viable mesophilic aerobes indicated a 4 log reduction in bacterial numbers in both cans and retort pouches (Table 3). Bacterial counts remained at levels obtained for freshly pasteurized meat for the duration of the 6 month study. Mesophilic anaerobes decreased by a log factor of over 4 (to less than 10) during pasteurization. Counts remained at this level

Table 3: Average microbial counts per gram of crabmeat packaged in retort pouches and cans pasteurized at 185°F (85°C) to an equivalent F_{185}^{16} of 24 for storage at 36°F (2.2°C).

	<u>Mesophilic</u>		<u>Psychrotrophic</u>		lactobacilli
	aerobes	anaerobes	aerobes	anaerobes	
Fresh	5.3×10^5	3.1×10^5	2.6×10^6	2.9×10^6	6.4×10^4
Week 0	3.9×10^1	≤ 10	1.9×10^1	≤ 10	≤ 10
Week 2 to 24 ^a	10 to 67 ^b	$\leq 10^c$	≤ 10	≤ 10	≤ 10

^a Product was analyzed at 2 week intervals for 24 weeks.

^b Five samples were ≤ 10 , 16 were 10 to 30, and 3 were 30 to 67.

^c Retort pouch count was 32 on week 10.

for the remainder of the study. However, one exception occurred on week 10 of pouch analysis. The sample pouches had an average bacterial count of 32.

Psychrotrophic aerobes in crabmeat decreased by a 5 log factor during pasteurization. Thereafter, these counts remained at levels less than 10 during the 6 months storage at 36°F (2.2°C). Psychrotrophic anaerobic counts of pasteurized crabmeat decreased by a log factor of 6 during pasteurization and were less than 10 for the duration of the study.

Lactobacilli counts of crabmeat after pasteurization decreased by a log factor of 4 (to less than 10). Lactobacilli were not detected for the remainder of the 6 month study.

Bacteriological evaluation is the most commonly used objective measurement of successful pasteurization (Tatro, 1970). According to Tatro (1970), bacteria should be absent in crabmeat immediately following pasteurization and during refrigerated storage.

Reductions in microbial populations following pasteurization were expected in this study because microorganisms generally associated with crabmeat are heat sensitive. Psychrotrophs probably account for the greatest percentage of organisms, but they are also the most heat sensitive, thus easily destroyed. Mesophilic organisms associated with crabmeat are not as heat sensitive, but pasteurization to 185°F (85°C) for 1 min is usually severe enough to destroy or significantly reduce them as well. In this study, pasteurization reduced microbial

populations by greater than 99%. However, bacteria were not absent. The Tri-State Seafood Committee (1969) has a more lenient requirement concerning the standard plate count. The Committee requires that samples of pasteurized crabmeat, taken within 24 hrs of processing, shall not have a standard plate count of more than 3×10^3 bacteria/g. However, if in pasteurized crabmeat fecal coliform bacteria are found, or if a total bacterial count in excess of 2.5×10^4 /g is found, it shall be construed as adulteration and subject to seizure and condemnation (Tri-State Sea Committee, 1979).

Pasteurized crabmeat should have a shelf life of 6 months when stored at temperatures below 36°F (2.2°C) (Flynn and Tatro, 1966; Tatro, 1970). In agreement with Flynn and Tatro (1966) and Tatro (1970), crabmeat pasteurized in retort pouches and cans was shelf stable for 6 months when stored at 36°F (2.2°C). Pasteurized crab cake mix was also found shelf stable for 6 months when stored at 36°F (2.2°C) (Loaharanu and Lopez, (1970). However, in their study, psychrotrophic counts /g of crab cake mix had increased by a log factor of 3 (1×10^4 to 1×10^7) after 6 months of storage, almost to the point of product unacceptability as judged by odor.

In summary, microbial counts in retort pouches and cans remained at levels of freshly pasteurized meat for the duration of the 6 month study, suggesting an estimated shelf life of 6 months. Also, retort pouch and can pasteurized crabmeat had approximately the same microbial loads. This was because the containers received equivalent levels of

pasteurization (pouches and cans had an $F_{185}^{16} = 24$). This suggests packaging and pasteurizing crabmeat in retort pouches would provide an acceptable alternative to packaging and pasteurizing crabmeat in cans.

In actuality, the pasteurization process given to retort pouches and cans in this study was a more severe test from a microbiological standpoint because the containers were slightly under processed. Industry currently pasteurizes crabmeat to an equivalent F_{185} value of 31 and in this study the containers were only pastuerized to an equivalent F_{185}^{16} value of 24. Thus, the low counts which resulted from pasteurizing crabmeat to an equivalent F value of 24 suggest that industry could safely reduce the pasteurization process currently given to cans.

E. Sensory Evaluation

Crabmeat can be marketed as freshly picked, frozen and pasteurized. However, storage limitations exist with the fresh and frozen product. Fresh crabmeat is highly perishable and is rendered unusable by its normal bacterial flora after 7 to 12 days of refrigerated storage (Cockey and Tatro, 1974). Freezing as a means of extending shelf life has not been successful for crabmeat. After a few weeks of frozen storage, the texture of the crabmeat becomes dry, tough and stringy; flavor becomes flat and off-odors develop (Banks et al., 1977).

The alternative to fresh and frozen crabmeat is pasteurized crabmeat. Pasteurization extends shelf life of crabmeat under refrigerated storage conditions (Dickerson and Berry, 1974). However, it does not improve its quality. Crabmeat is extremely sensitive to heat (Tatro,

1970). Thus, the objective of pasteurizing crabmeat is to extend refrigerated shelf life by using minimal heat treatments.

Sensory evaluation of crabmeat involves judging taste, color, texture, odor and overall acceptability. According to Tatro (1970), there is little significant difference between pasteurized and fresh crabmeat when it has been properly pasteurized and cooled. The flavor and aroma of fresh crabmeat should be retained in the pasteurized product. Also, the pasteurized meat should be firm, and its color should not should show a gray or blue cast (Tatro, 1970).

When evaluating the quality of a food product, it is difficult to arrive at a definite conclusion concerning the product's quality. This is especially true of crabmeat where the standards of quality for the entire history of the industry have been those of individual preferences for taste, odor and appearance (Littleford, 1958).

In this study, crabmeat pasteurized in retort pouches and cans was evaluated. Flavor, color, texture, odor and overall acceptability were considered. Taste panel results are presented in Table 4.

Preference for crabmeat packed and pasteurized in retort pouches or cans was most apparent for flavor. Crabmeat pasteurized in retort pouches was significantly better ($P \geq 0.05$) on weeks 1, 4 and 8. Although meat pasteurized in retort pouches was not significantly better for the remaining weeks, average scores for pouches were higher.

The attributes color, texture and odor showed the least variability in scores between crabmeat pasteurized in retort pouches and cans. The

Table 4: Taste panel results of crabmeat packed in retort pouches (113.5 g) and 2 1/2 x 1 1/4 cans (113.5 g) and pasteurized to an equivalent F₁₈₅¹⁶ of 24 at 36°F (2.2°C)^{1,2,3}

Week	Flavor		Color		Texture		Odor		Overall Acceptability	
	I ⁴	II	I	II	I	II	I	II	I	II
1	7.44a ⁵	6.75b	7.38a	7.44a	7.44a	7.44a	7.00a	6.88a	7.44a	6.94a
4	7.22a	6.61b	7.22a	6.89a	7.72a	7.50a	7.61a	7.00b	7.61a	7.06b
8	7.20a	6.45b	6.90a	6.95a	7.35a	6.95b	7.30a	7.00a	7.35a	6.75b
12	6.61a	6.28a	6.61a	6.56b	7.06a	6.78a	6.67a	6.78a	7.00a	6.78a
16	7.19a	6.18a	7.19a	6.88a	7.06a	7.13a	7.25a	7.31a	7.25a	7.13a
20	6.06a	5.94a	6.44a	5.88a	6.44a	6.13a	6.06a	5.94a	6.31a	5.90a
24	6.81a	6.38a	6.69a	6.31a	6.38a	6.19a	6.19a	6.06a	6.50a	6.13a

¹ Values are mean scores of 10 panel members.

² Attributes scored on hedonic scale from 1-9 (1 = extremely unacceptable, 9 = extremely acceptable).

³ Week 0 analysis not done because it took 4 days to obtain estimated microbial counts.

⁴ Roman numerals refer to: I - retort pouch pasteurized crabmeat, II - can pasteurized crabmeat.

⁵ Values in the same row for each quality characteristic with different lower case letters are significantly different ($P \leq 0.05$).

color of the crabmeat packaged in retort pouches and cans was not significantly different ($P \geq 0.05$) for the duration of the study. Texture of crabmeat processed in retort pouches was significantly better ($P \geq 0.05$) than crabmeat packed in cans on week 8. No significant differences were detected on remaining weeks. Odor of crabmeat packaged in pouches was significantly better ($P \geq 0.05$) than cans on week 4. No significant differences were detected on remaining weeks.

Significant differences ($P \geq 0.05$) were found in overall acceptability on weeks 4 and 8. Crabmeat pasteurized in retort pouches was preferred. Although significant differences were not detected during the remaining weeks, scores for pouches were consistently higher.

Hedonic scores also indicate how satisfied a judge is with a particular food product. This is one advantage of using this type of scoring system. For example, one product may receive a significantly higher score than another (i.e., 6 vs. 2). However, both products could end up being unsatisfactory to industry since the product with the higher score was only judged "slightly acceptable".

In this study, hedonic scores of crabmeat pasteurized in retort pouches were 7.2 for each of attributes tested on weeks 1, 4, 8, 12 and 16. This is in the very acceptable - moderately acceptable range. Crabmeat pasteurized in cans received average scores of 6.9 for each of the attributes tested on these weeks. This is in the moderately acceptable - slightly acceptable range. However, panelists were less satisfied with the crabmeat packed in retort pouches and cans on weeks 20

and 24. Average scores were approximately 6.4 and 6.1 for pouches and cans, respectively. However, crabmeat was still in the acceptable range.

Unfortunately, very little information has been published on the sensory evaluation of crabmeat. Flynn and Tatro (1966) reported no significant difference between crabmeat packaged and pasteurized in metal and plastic containers until after three and one-half months storage at 33 to 35°F (0.6 to 1.7°C). However, after this time there was a significant difference ($P \geq 0.05$) in appearance and flavor with a preference for meat stored in plastic containers. It was noted that metal containers rendered a grayish tint to the meat and imparted a slight metallic taste. No significant difference in texture was detected during storage.

The slight preferences observed for crabmeat packaged and pasteurized in retort pouches in this study could have been related to decreased processing time. Processing time is less because the geometric configuration of the pouch allows for rapid heating and cooling. This is important because crabmeat is sensitive to heat (Tatro, 1970). Therefore, minimal heat treatments are highly desirable. Also, one would expect meat quality to be better if time of heat exposure was less. According to Heintz (1980), reduced heat exposure results in improved food product quality with better taste, color and texture than similar products processed in cans. Tatro (1970) noted that excessive heat can cause toughening and darkening of crabmeat.

In this study, some preferences for taste, texture, odor and overall

acceptability were indicated for crabmeat packaged and pasteurized in retort pouches. However, no preferences were indicated for color. Results of this study suggests that packaging crabmeat in retort pouches rather than cans is an acceptable, if not superior, method of pasteurization.

V. SUMMARY AND CONCLUSIONS

The feasibility of packaging and pasteurizing crabmeat in retort pouches compared to cans was investigated. Retort pouch suitability was evaluated with regard to heat penetration, process lethality, microbiological stability and sensory evaluation.

Heat penetration rates were determined with retort pouches and cans (401 x 301, 303 x 406, 307 x 206 and 211 x 114) packed with 454.0 g, 227.0 g, and 113.5 g of crabmeat, respectively. Heating, cooling and total processing times were significantly less ($P \geq 0.05$) for crabmeat packaged in retort pouches than cans of equal net weight. The thinner profiles and increased surface area of retort pouches permitted rapid heating and cooling.

The process lethalities (F values) which resulted from pasteurizing all containers to 185°F (85°C) for 1 min were significantly less ($P < 0.05$) for retort pouches than cans of equal net weight. This was expected. Retort pouches spent less time in the lethal temperature range of 180°F to 185°F (82.2 to 85°C) because of their rapid heating and cooling rates.

Crabmeat was microbiologically evaluated for mesophilic aerobes and anaerobes, psychrotrophic aerobes and anaerobes, and lactobacilli. Microbial populations were reduced after pasteurization to a target F_{185}^{16} value of 24 by greater than 99% in both retort pouches and cans. This reduction was maintained during 6 months storage at 36°F (2.2°C). In

addition, retort pouches and cans had approximately the same microbial loads for the duration of the study. This was expected because the containers were pasteurized to an equivalent F_{185}^{16} value of 24.

Sensory evaluations indicated no real preference for flavor, color, texture, odor and overall acceptability of crabmeat pasteurized in pouches and cans. However, significant preferences ($P \leq 0.05$) for crabmeat pasteurized in retort pouches were observed on some weeks. Hedonic scores indicated that crabmeat pasteurized in pouches and cans were in the acceptable range during the 6 month study.

Packaging and pasteurizing crabmeat in retort pouches would be beneficial both for industry and consumer. Energy costs associated with processing would be lower and product quality would be better.

Also, giving time-temperature parameters of a process in terms of a target F value would provide a rapid and efficient way to achieve equivalent processes.

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APPENDIX I

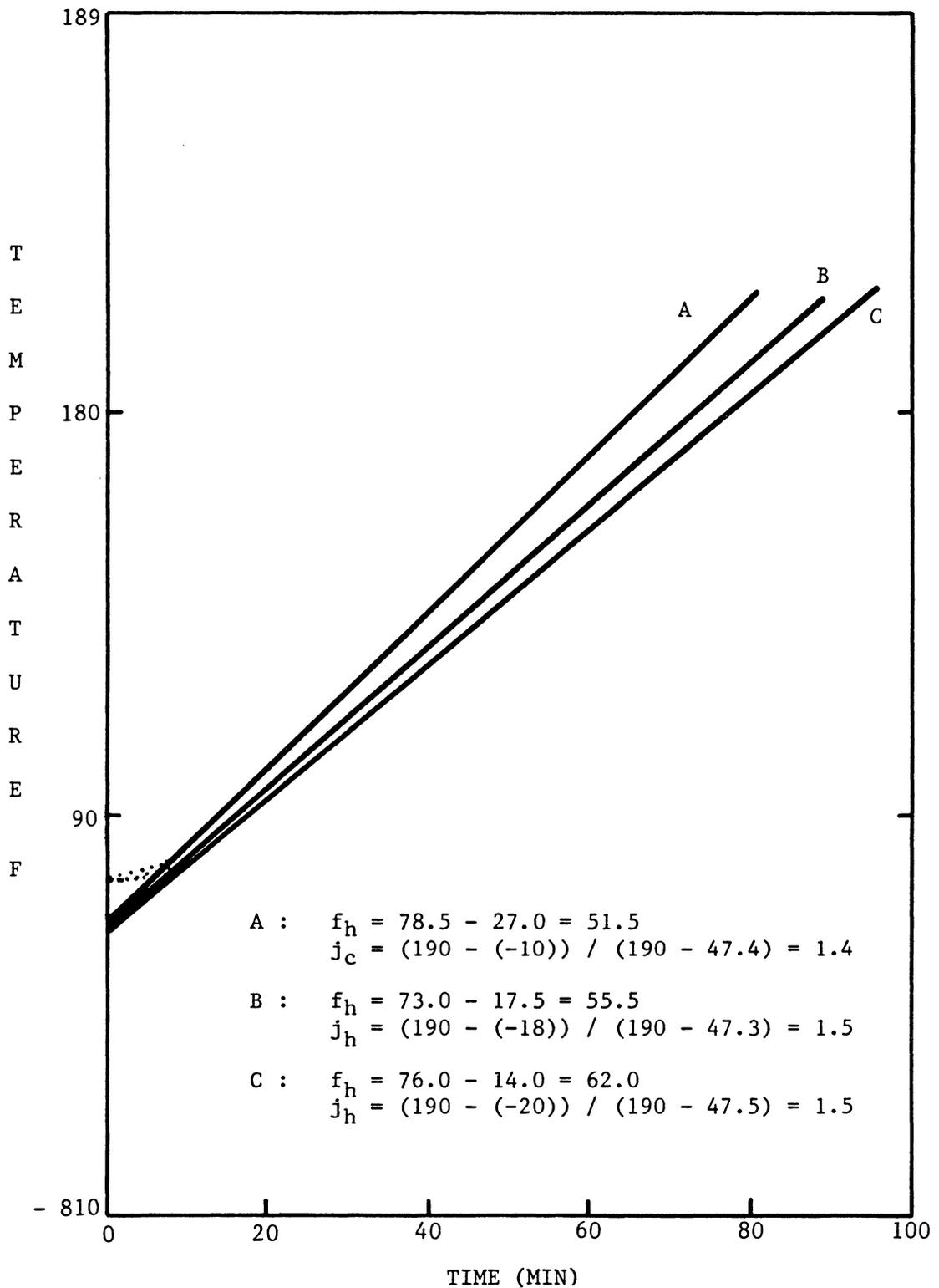


Figure 1. Semilogarithmic heating curves for retort pouches (A), 303 x 406 cans (B) and 401 x 301 cans (C) containing 454.0 g of crabmeat.

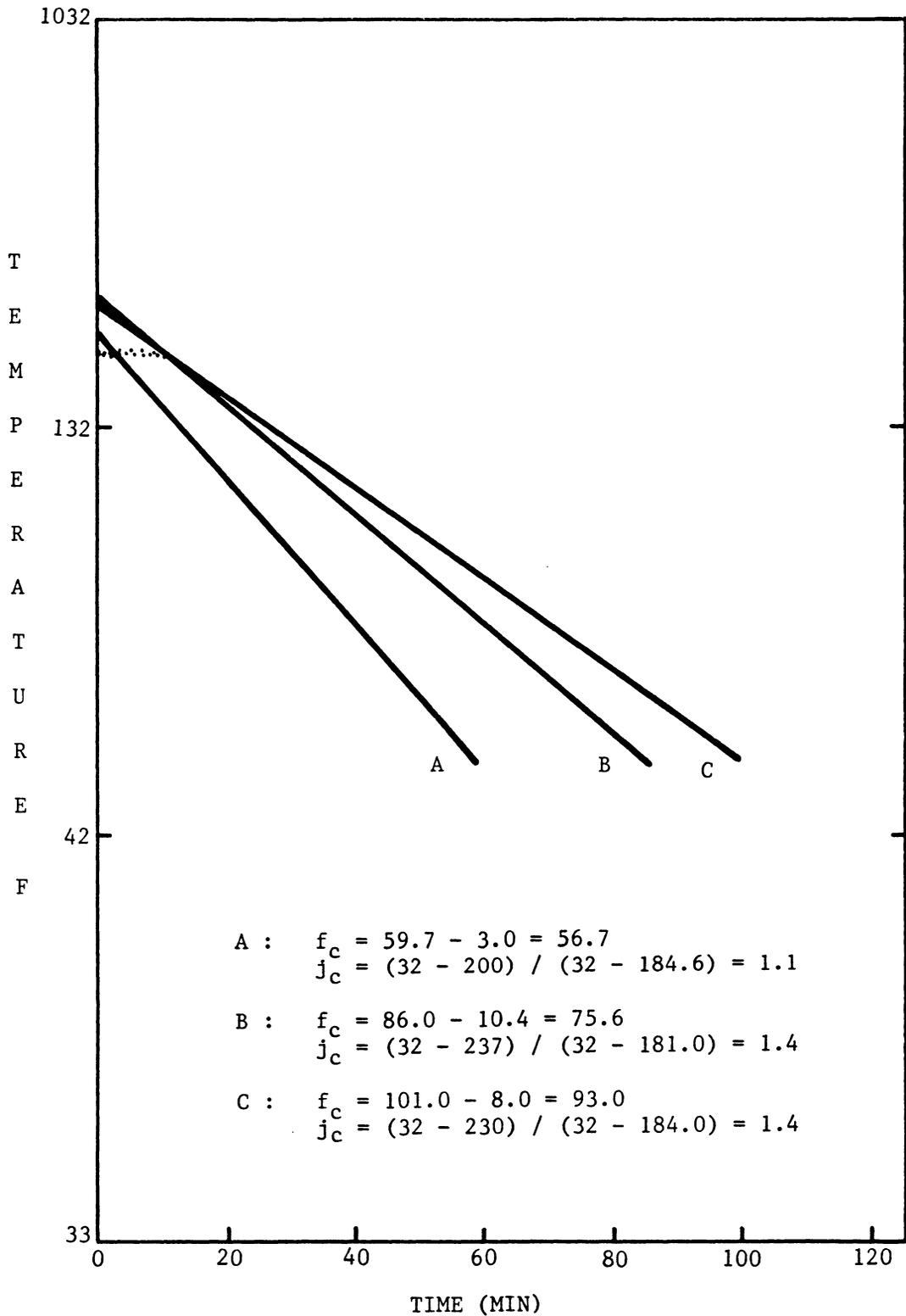


Figure 2. Semilogarithmic cooling curves for retort pouches (A), 303 x 406 cans (B) and 401 x 301 cans (C) containing 454.0 g of crabmeat.

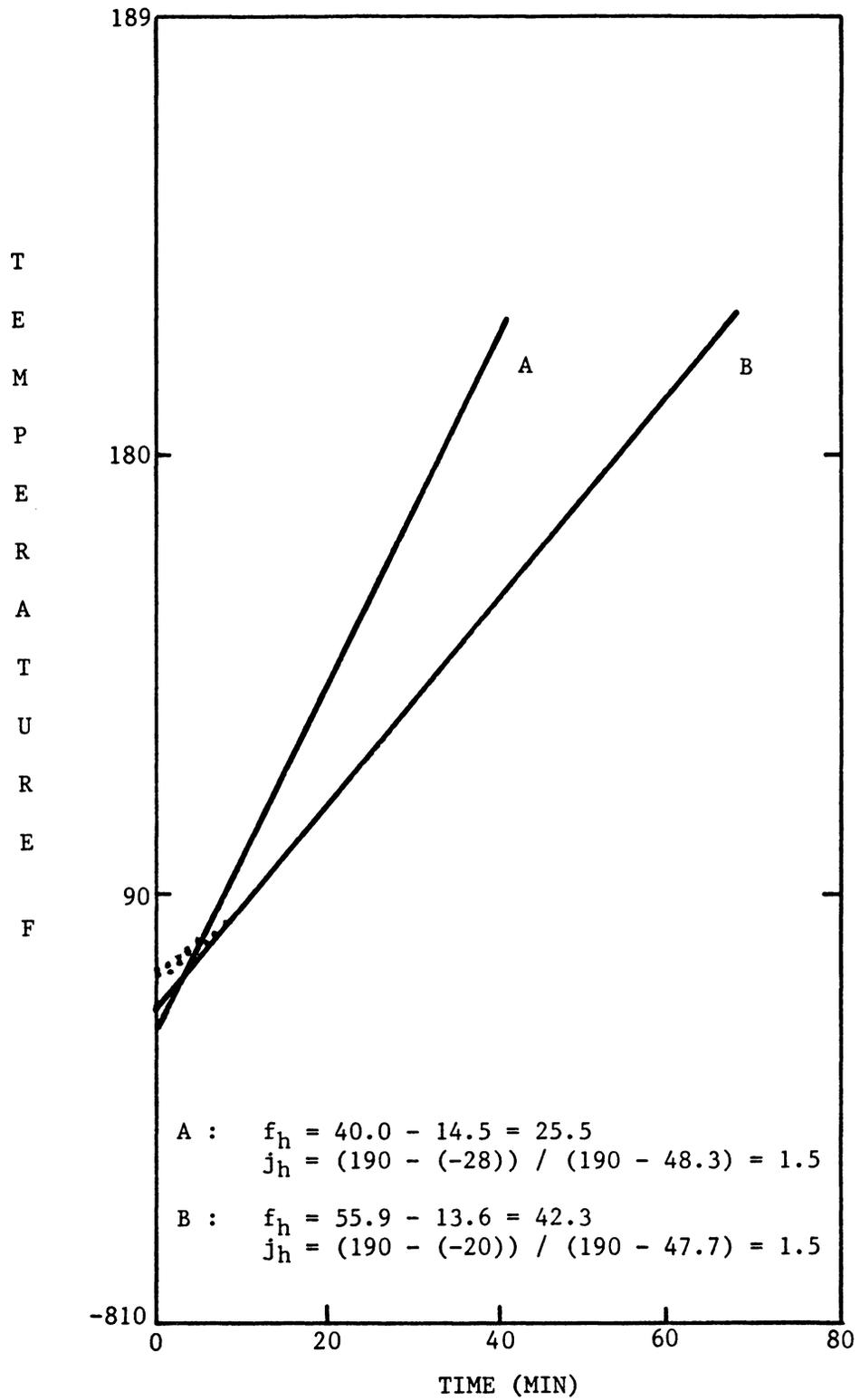


Figure 3. Semilogarithmic heating curves for retort pouches (A) and 307 x 206 cans (B) containing 227.0 g of crabmeat.

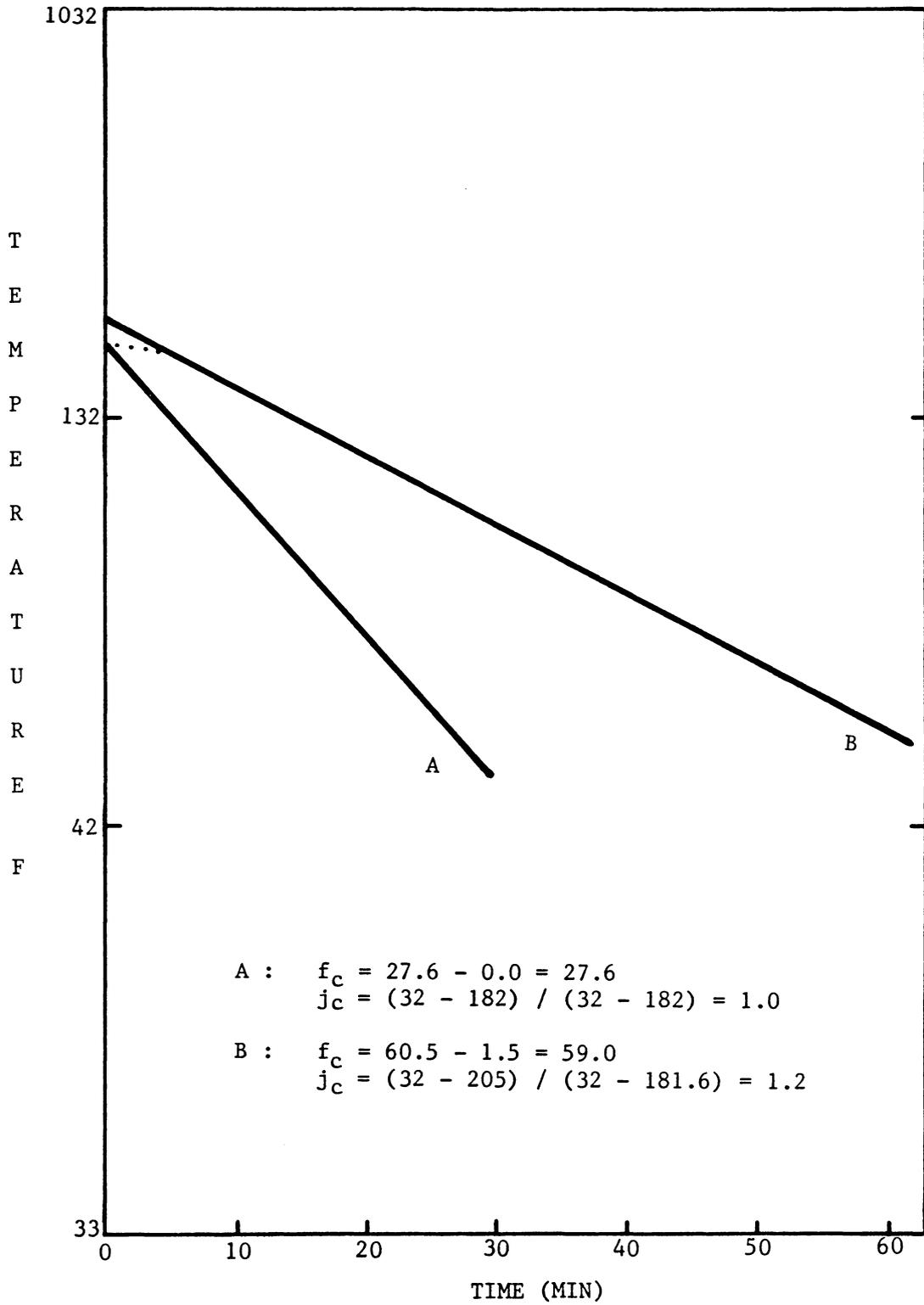


Figure 4. Semilogarithmic cooling curves for retort pouches (A) and 307 x 206 cans (B) containing 227.0 g of crabmeat.

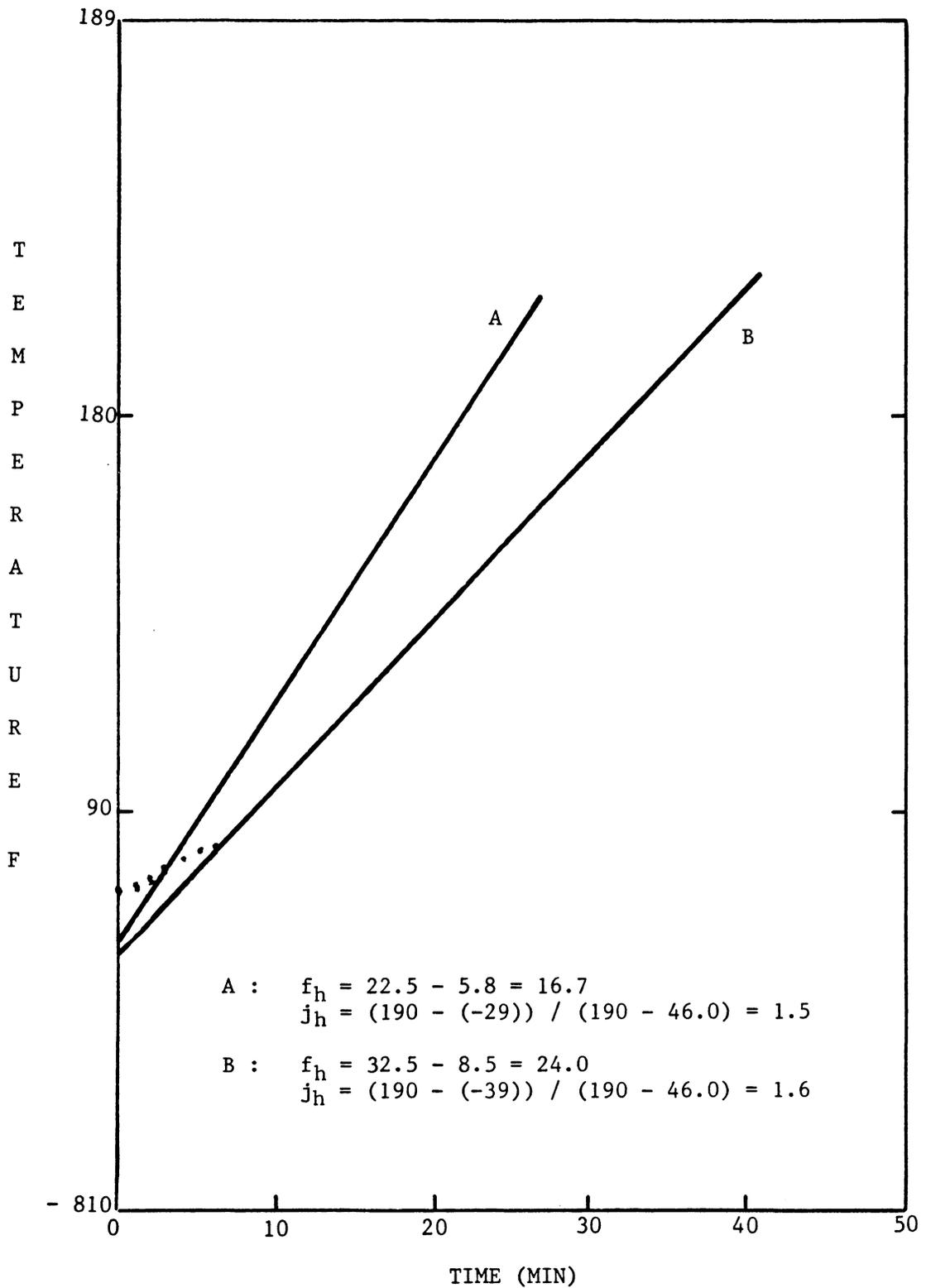


Figure 5. Semilogarithmic heating curves for retort pouches (A) and 211 x 114 cans (B) containing 113.5 g of crabmeat.

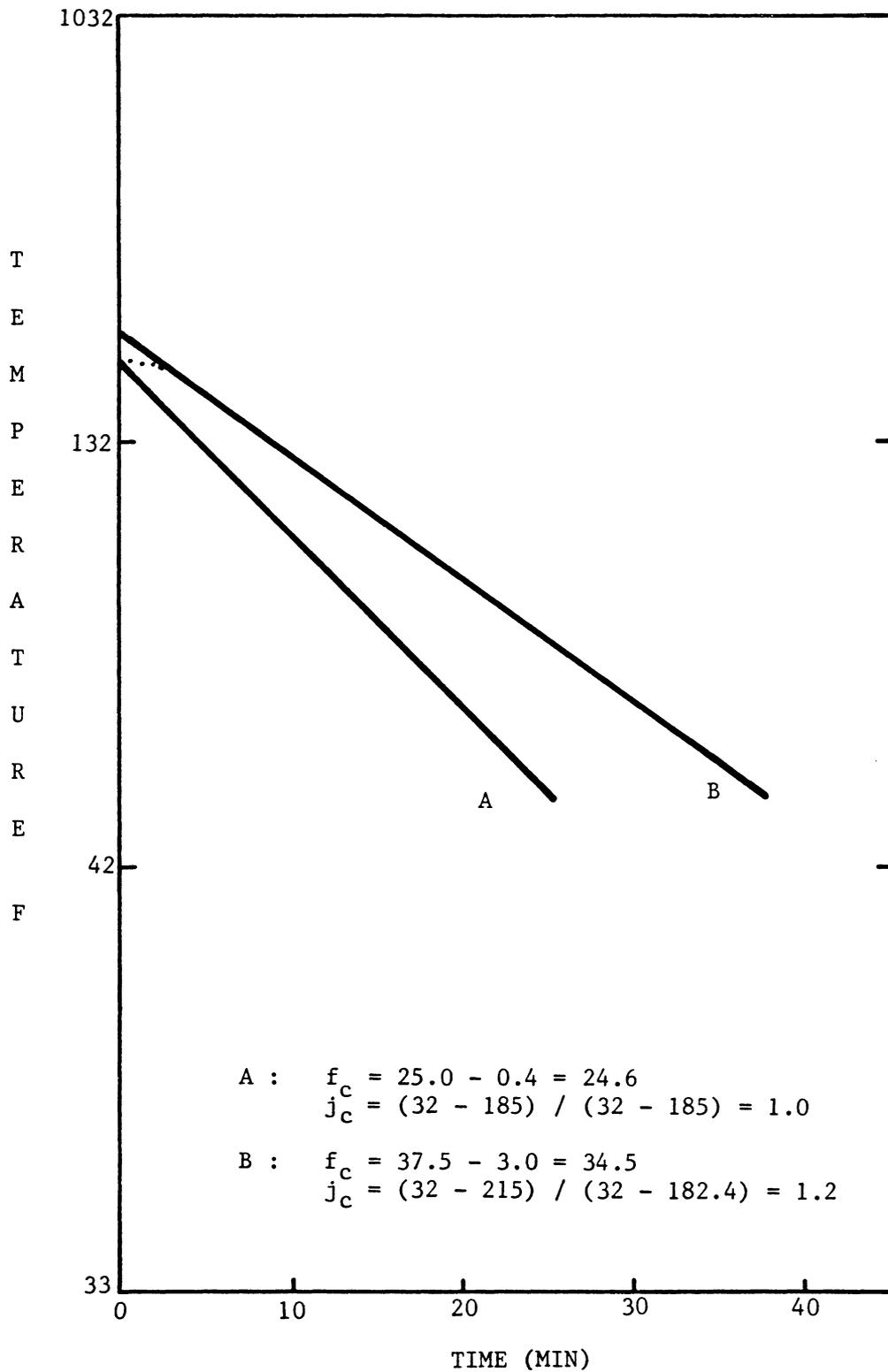


Figure 6. Semilogarithmic cooling curves for retort pouches (A) and 211 x 114 cans (B) containing 113.5 g of crabmeat.

APPENDIX II

LIST OF DEFINITIONS¹

- D Time required at a specific temperature to destroy 90% of the spores or vegetative cells of a given organism. Numerically, equal to the number of minutes required for the survivor curve to traverse 1 log cycle. Mathematically, equal to the reciprocal of the slope of the survivor curve.
- F Equivalent time, in minutes at a specific temperature, of all lethal heat in a process with respect to its capacity to destroy an organism characterized by some given z value.
- f_c Time, in minutes, required for the straight-line portion of the semilog cooling curve to traverse 1 log cycle. It represents the slope of the curve. Numerically, it is equal to the reciprocal of the slope.
- f_h Time, in minutes, required for the straight-line portion of the semilog heating curve to traverse 1 log cycle. It represents the slope of the curve. Numerically, it is equal to the reciprocal of the slope.
- j_c This is often referred to as the cooling lag factor. It is a factor which, when multiplied by the difference between cooling water temperature and food temperature, locates the intersection of the extension of the straight-line portion of the cooling curve and the vertical line representing the beginning of cooling.
- j_h This is often referred to as the heating lag factor. It is a factor which, when multiplied by the difference between heating water temperature and food temperature, locates the intersection of the extension of the straight-line portion of the heating curve and the vertical line representing the beginning of heating.
- z Degrees Fahrenheit required for the thermal destruction curve to traverse 1 log cycle. Mathematically, equal to the reciprocal of the slope of the thermal death curve.

¹Stumbo, 1973

APPENDIX III

A. Form for Taste Panel Evaluation of Crabmeat

Date _____

Judge's Name _____

You will be given samples of crabmeat and asked to evaluate each sample on the basis of odor, flavor, color, texture, and overall acceptability. Please evaluate each sample by using the following hedonic rating scale:

- 9 - Extremely acceptable
- 8 - Very acceptable
- 7 - Moderately acceptable
- 6 - Slightly acceptable
- 5 - Neither acceptable or unacceptable
- 4 - Slightly unacceptable
- 3 - Moderately unacceptable
- 2 - Very unacceptable
- 1 - Extremely unacceptable

I would greatly appreciate any comments you might have on the sample.

	Sample			
	A	B	C	D
Odor	_____			
Flavor	_____			
Color	_____			
Texture	_____			
Overall Acceptability	_____			
Comments:				

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the scanned document**

FEASIBILITY STUDY FOR PACKAGING AND PASTEURIZING
MEAT OF THE BLUE CRAB, CALLINECTES SAPIDUS, IN RETORT POUCHES

by

Marianne Snow Minnick

(ABSTRACT)

The purpose of this research was to determine the feasibility of pasteurizing crabmeat in retort pouches compared to cans. Retort pouches and cans were packed with various amounts of crabmeat, pasteurized to an internal temperature of 185°F (85°C) for 1 min, and subsequently cooled. The criteria for evaluation were total processing time, process lethality (F value), microbiological stability and sensory evaluation.

Pasteurizing crabmeat in retort pouches resulted in total processing times that were significantly less ($P \geq 0.05$) than cans. Also, pasteurizing to targeted F values provided a more rapid and efficient way to achieve equivalent processes. Thus, equivalent can processes were given to pouches in significantly less ($P \geq 0.05$) time.

Microbial loads were reduced by greater than 99% in both pouches and cans following pasteurization to a target F value ($F_{185}^{65} = 24$). This reduction was maintained during 6 months storage at 36°F (2.2°C).

Sensory evaluations conducted over a 6 month period indicated no real preference for crabmeat packaged in retort pouches or cans. However, crabmeat packed in pouches was significantly better ($P \geq 0.05$) on some weeks. Hedonic scores indicated meat in both types of containers were acceptable for the duration of the study. It was concluded that packaging and pasteurizing crabmeat in retort pouches is an acceptable, if not superior, method of pasteurization.