ANTIOXIDANT PROPERTIES OF PHOSPHOLIPIDS IN A SALMON OIL MODEL SYSTEM

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INTRODUCTION

During the processing of both seed oils and fish oils, the major content of phospholipids is removed during the washing and clean-up of crude lipid extracts. Since phospholipids (PL) are generally of higher unsaturation, a great deal of emphasis has been placed on their effective removal to assure enhanced stability of refined oils. Recent studies (12,5), however, have shown that the addition of small quantities of PL possessed antioxidant properties in enhancing the storage stability of processed vegetable oils and animal fats. Previous studies in the authors laboratory (7) have also shown that the addition of PL extracted from bluefish (Pomatomus salatrix) to a salmon oil model system had greater antioxidant properties than Neutral lipids in spite of the higher polyunsaturated fatty acid content of the PL. There, the objectives of this study were to measure the antioxidant properties of selected PL in a heated salmon oil model system and to examine the relationship between color intensity and antioxidant property.

METHODS

Commercial phospholipid standards of greater than 98% purity were obtained from Sigma Chemical Co (St. Louis, MO). These PL standards included Phosphatidylcholine (PC), phosphatidylethanolamine (PE), phosphatidylglycerol (PG), phosphatidyl serine (PS), sphingomyelin (SPH), and phosphatidylinositol (PI). The PE, PC, SPH, and PG were obtained from egg yolk, whereas the PS and PI were obtained from bovine brain and liver, respectively. The salmon oil was obtained from Body Products Research, Inc. (Chatsworth, CA) without the addition of stabilizers or antioxidants. Prior to
use, the endogenous phospholipid contents of the oil and of the commercial PL were checked by high performance liquid chromatography (HPLC) (4) and phosphorus analyses (1).

**Model oil systems:** All PL standards were dissolved in chloroform-methanol (2:1, v/v) prior to their addition to 20 mg of salmon oil (SO), followed by vortexing and evaporation of solvent under a stream of nitrogen. All treatments were placed in screw-cap glass test tubes without caps and heated in a forced-draft oven at 180° C for periods of 0, 15, 30, 60, 120, and 180 min.

**Experiment I:** The first experiment consisted of four treatments that included (1) control salmon oil-no PL, (2) SO + 0.01% PC, (3) SO + 0.10% PC and (4) SO + 1.0% PC.

**Experiment II:** Treatments consisted of the following (1) control: SO-no PL (2) SO + 1% PG, (3) SO + 1% PI, (4) SO + 1% PS, (5) SO + 1% PE, (6) SO + 1% PC (7) SO + 1% LPC, and (8) SO + 1% SPH.

**Test of Oxidative Stability:** The oxidative stability of the model systems was determined by measuring the change in fatty acid composition (Polyene ratio) (11), and the formation of malonaldehyde as measure by the 2-thiobarbituric acid assay (TBA) (6). The polyene ratio or index was measured by gas chromatographic analysis (9) of fatty acids expressed as the ratio polyunsaturated fatty acids(PUFA) to saturated (SAT) fatty acids using the loss of docosahexaenoic acid (DHA) to palmitic acid (i.e. C22:6/C16:0) as the index of oxidation. A Hewlett Packard, Model 5890 (Avondale, PA) equipped with a flame ionization detector was used to analyze prepared methyl esters (8). As an indicator of the possible formation of browning reaction products, 20 mg aliquots from each treatment were removed for spectrophotometric measurement of color changes using a Shimadzu Recording Spectrophotometer UV-240 (Schimadzu Corp., Kyoto, Japan) set at 430 nm (3).

**Statistical Analysis:** A randomized complete block design containing two replication was used to analyze all data (2,10).

**RESULTS AND DISCUSSION**

The addition of PC at all three levels improved the overall stability of salmon oil subjected to thermal stress at 180° C
(Fig. 1A). Additions of PC at the 1% level appeared to be most effective in reducing TBA values, whereas additions at 0.01% and 0.10% did not differ significantly from each other. The polyene index showed a pattern similar to TBA values in that additions at the 1% and 0.10% levels were most effective in preserving PUFA. Additions of PC at the 0.01% did not differ significantly from the control containing no PC.

Examination of the change in color intensity measured at 490 nm (Fig. 2) indicate that increasing concentrations of PC were associated with increasing color intensity. Additions of PC at the 0.01% and 1.0% were significantly higher than control and 0.01%, which did not differ from each other. Comparisons of TBA numbers, polyene index, and color intensity indicate significant correlations between the three parameters as well as length of heating (Table 1). For example, TBA values were inversely correlated to PC levels at the 30 and 60 min heating periods, whereas the polyene index was strongly correlated to PC levels toward the end of the heating cycle reflecting the generally slower loss of PUFA over time.

The results of experiment II indicate that the PL differed in their ability to control oxidation of PUFA subjected to heated storage (Fig. 3). The nitrogen-containing PL including PE, PC, LPC, and SPH appeared to be the most effective in stabilizing the oil whereas PG and PI were least effective. Examination of TBA numbers over various periods of heating indicate that while PI, PS, and PG were effective in increasing the induction period, they were not as effective as the nitrogen-containing PL over the entire course of heating. The polyene index values showed a pattern similar to that observed TBA numbers in that the antioxidant properties of PE, PC, LPC, and SPH were not significantly different from each other whereas PS, PI, PG, and the control were ineffective in controlling the loss of PUFA.

The change in color intensity followed a pattern similar to that observed in experiment I in that the most effective PL possessed the highest color intensity whereas the least effective PL showed increases in color intensity similar to the control containing no PL. However, there were differences in the rate of increases that appeared to be influenced by the effectiveness of certain PL. For example, treatments
Fig. 1: Model system I-Effects of 0.01, 0.10, and 1.0% phosphatidylcholine (PC) on (A) 2-thiobarbituric acid (TBA) numbers and (B) polyene index of salmon oil heated to 180° C for 180 min.
Fig. 2: Model system 1- Effects of 0.01, 1.0 and 1.0% phosphatidylcholine (PC) on absorbance values of salmon oil measured at 430 nm heated to 180° C for 180 min.
Fig. 3: Model system II-Effects of 1% additions of different classes of phospholipids on (A) thiobarbituric acid number (TBA) and (B) absorbance values of salmon oil heated to 180°C for 180 min.

*PG=phosphatidylglycerol; PI=phosphatidylinositol; PS=phosphatidylserine; PE=phosphatidylethanolamine; SPH=sphingomyelin; PC=phosphatidylcholine; LPC=lysophosphatidylcholine.
Table 1. Simple correlation coefficients between TBA numbers, polyene index, and browning color of salmon oil, and salmon oil + 0.01%, 0.1% and 1% Phosphatidylcholine over different heating times at 180° C.

<table>
<thead>
<tr>
<th>Heating time (min)</th>
<th>Polyene ratio (22:6/16:0)</th>
<th>Browning</th>
<th>% of PC added</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-0.56</td>
<td>-0.52</td>
<td>0.45</td>
</tr>
<tr>
<td>TBA numbers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyene ratio</td>
<td>-0.44</td>
<td>-0.47</td>
<td></td>
</tr>
<tr>
<td>Browning</td>
<td></td>
<td></td>
<td>0.84**</td>
</tr>
<tr>
<td>30</td>
<td>-0.72</td>
<td>-0.82**</td>
<td>-0.93**</td>
</tr>
<tr>
<td>TBA numbers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyene ratio</td>
<td>0.94**</td>
<td>0.87**</td>
<td></td>
</tr>
<tr>
<td>Browning</td>
<td></td>
<td></td>
<td>0.95**</td>
</tr>
<tr>
<td>60</td>
<td>-0.78</td>
<td>-0.64</td>
<td>-0.95**</td>
</tr>
<tr>
<td>TBA numbers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyene ratio</td>
<td>0.83**</td>
<td>0.74*</td>
<td></td>
</tr>
<tr>
<td>Browning</td>
<td></td>
<td></td>
<td>0.57</td>
</tr>
<tr>
<td>120</td>
<td>-0.66</td>
<td>-0.69</td>
<td>-0.70</td>
</tr>
<tr>
<td>TBA numbers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyene ratio</td>
<td>0.90**</td>
<td>0.84**</td>
<td></td>
</tr>
<tr>
<td>Browning</td>
<td></td>
<td></td>
<td>0.86**</td>
</tr>
</tbody>
</table>

* (P < 0.05).
** (P < 0.01).
containing PE and PS showed very rapid increases in color intensity within 1 hr of heating whereas treatments containing LPC, SPH, and PC showed more gradual increasing in color intensity.

The correlation patterns of Experiment II were the same as observed in Experiment I in that TBA values were negatively correlated with the formation of browning reaction products and the polyene index. However, color intensity was positively correlated with the polyene index, indicative of the preservation of PUFA by the addition of selected PL.

Table 2 shows the change in fatty acid concentration of the control salmon oil and the treatments containing PL prior to and following heating over the course of the 3 hr heating. As can be observed from the initial zero period of heating, the total PUFA content as well as the total n-3 PUFA content of the controls and of the treatments containing PL did not differ significantly from each other. However, following 3 hr of heating, the total PUFA content, n-3 PUFA as well as n-3/SAT ratio showed major differences in the ability of the PL to protect the stability of the heated oil. The SPH and LPC appeared to be equally most effective in stabilizing the lipid, followed by PC and PE. Treatments containing PG, PS, and PI were ineffective and did not differ from the control salmon oil containing no PL. The fatty acid composition of the individual PL also did not appear to have an impact on the antioxidant properties of the PL as PG and PC were almost identical in fatty acid composition yet differed significantly in their antioxidant properties.

CONCLUSION

The results of these studies demonstrated that the addition of selected PL enhanced the oxidative stability of salmon oil model systems subjected to heated storage. The nitrogen containing PL including PC, PE, SPH, LPC appeared to have the greatest antioxidant properties whereas PL containing glycerol (PG) and a reducing sugar (PI) were least effective. The addition of PC at different concentrations indicated a concentration gradient whereas the addition of different PL indicated that the antioxidant properties were not related to the fatty acid composition of the PL. The formation of
Table 2. Changes in fatty acid concentration of salmon oil and salmon oil plus 1% commercial PL during heating at 180°C for 3 hr

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>OIL</th>
<th>+PG</th>
<th>+PI</th>
<th>+PS</th>
<th>+PE</th>
<th>+PC</th>
<th>+LPC</th>
<th>+SPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>35.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>33.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>29.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.83&lt;sup&gt;ab&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>43.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>16.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>13.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.39&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>51.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.9&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.10&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>180</td>
<td>56.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.02&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a, b, c</sup> Means with different letter superscripts within heating time and fatty acid category indicate a significant difference between treatments (p<0.05). Treat = treatment, SAT = saturated, MONO = monounsaturated, PUFA = polyunsaturated fatty acids with two or more double bonds, n-3 = total of all fatty acids with n-3 double bonds, Sin-3 = combined C20:5 and C22:6, n-3/SAT = total n-3 fatty acids/saturated fatty acids, PG = phosphatidylglycerol, PS = phosphatidylserine, PL = Phospholipid, PE = Phosphatidylethanolamine, PC = phosphatidylcholine, LPC = Lysophosphatidylcholine, PI = phosphatidylinositol, SPH = sphingomyeolin, C18:2 = linoleic acid.
browning reaction products and their effectiveness in stabilizing the salmon oil model system appears to be similar to the formation of Maillard reaction products which have been shown to have antioxidant properties in heated systems.

REFERENCES


Acknowledgments

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EVALUATION OF PACKAGING ALTERNATIVES FOR FRESH AND PASTEURIZED CRAB MEAT

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Blue crab processors need packaging options for fresh and pasteurized crab meat that reduce processing and packaging costs, improve quality, safety, and shelf life, and accommodate smaller portion sizes. Traditional fresh and pasteurized crab meat containers are 16 oz polyethylene cups and 16 oz steel cans, respectively. Processors have been presented with a number of new commercial options for the packaging of both fresh and pasteurized crab meat. Little data is available to processors that would permit an objective evaluation of the effects of the new packaging materials on pasteurized or fresh picked crab meat stored on ice or at refrigerated temperatures. The following is a preliminary report of a continuing study to determine the effectiveness of commercial packaging materials on the quality, shelf life, and safety of fresh and pasteurized crab meat.

METHODS

Over a 10 month period lump meat pasteurized at 182°F was held between 32°F and 34°F in the following containers: (i) 16 oz steel cans (#401); (ii) 10 oz plastic cans with aluminum easy-open ends (#307 co-polymer polyethylene cans holding 8 oz of crab meat, King Plastic Corporation, Orange, CA); (iii) 8 oz aluminum cans (#307 with easy-open ends); (iv) 8 oz non-barrier pouches (Cryovac P640 with nylon base and low density polyethylene sealant); and (v) 8 oz barrier pouches (Cryovac P640B with nylon base Saran® barrier and low density polyethylene sealant, Cryovac Corporation, Duncan, SC).

Webster et al. (14) determined that crab meat spoiled during refrigerated storage following pasteurization conditions that achieved a minimum $F_{56}$ value of 31 minutes, the process equivalent recommended by the National Blue Crab Industry Pasteurization Guidelines. Webster et al. (14) isolated two heat tolerant organisms that were identified as a Bacillus sp. and a Clostridium sp. All cans were processed to an $F_{56}$-value of approximately 40 minutes, in an effort to reduce the potential for bacterial spoilage in the investigated packaging materials. Cans were pasteurized in water at 182°F. Calculated $F$-values and cook times for each pasteurized can type can are shown in Table 1 (5,6).
Samples were collected from three containers of each can type and composited for: chemical, microbiological, and sensory analyses at zero time, 2, 4, 6, 8, and 10 months. Analyses were completed in duplicate. The study will be continued through 1 year of refrigerated storage.

**TABLE 1.** Cook times and calculated F-**values** for lump crab meat pasteurized at 182°F in the five investigated containers.

<table>
<thead>
<tr>
<th>CAN TYPE</th>
<th>COOK TIME (MINUTES)</th>
<th>F-VALUE (MINUTES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEEL CAN</td>
<td>163</td>
<td>53.8</td>
</tr>
<tr>
<td>PLASTIC CAN</td>
<td>130</td>
<td>43.8</td>
</tr>
<tr>
<td>ALUMINUM CAN</td>
<td>120</td>
<td>39.7</td>
</tr>
<tr>
<td>BARRIER POUCH</td>
<td>70</td>
<td>42.8</td>
</tr>
<tr>
<td>NON-BARRIER POUCH</td>
<td>70</td>
<td>45.2</td>
</tr>
</tbody>
</table>

The following parameters were evaluated during 10 months of refrigerated storage. A Minolta Chroma Meter CR-200 (Minolta Corporation, Ramsey, NJ) was used to determine Hunter L, a, b color values of the meat (8). Whiteness index (WI) was calculated according to Stensby (12): $WI = L - 3b + 3a$. Stensby's whiteness index was adopted from the detergent industry where it has been used to determine the relative whiteness of fabrics. The index provides a quantitative evaluation of crab meat color. The index assigns 3 times as much weight to Hunter a, green levels, and Hunter b, blue levels, as it does to Hunter L or lightness levels. Components of blue and green create undesirable colors in blue crab meat. Stensby's whiteness index has not been correlated to the visual assessment of crab meat color. Aerobic and psychrotroph plate counts were determined using standard dilution techniques (11). Ammonia levels (13) and pH (7) were measured. A five member trained panel developed sensory odor profiles on a continuous scale from 0 to 6 with 0 being none detected and 6 the strongest possible response for ammonia, sour, putrid, and crab odors (1,2,3,5,9). The panel's subjective like or dislike of meat color and appearance was rated on a continuous scale from 0 to 6.

Fresh special crab meat was held at 32°F or 39.2°F in the following: (i) 12 oz polyethylene cups; (ii) 8 oz polystyrene trays over-wrapped with SaranR (PVDC, polyvinylidene chloride film, Dow Chemical Co., Indianapolis, IN); (iii) 8 oz permeable pouches (Cryovac P640 with nylon base and low density polyethylene sealant, Cryovac Corporation, Duncan, SC) packaged using a Multivac AG 900 vacuum packaging machine (Multivac Sepp Haggenmüller KG, West Germany); and (iv) 8 oz polystyrene trays vacuum skin packaged by sealing film-to-tray with Trigon oxygen permeable IntactR Skin Packaging Film (ISPF) using a Trigon RM331 Mark III Mini IntactR machine (Trigon Packaging Corporation, Redmond, WA). Composite samples were collected at 0, 3, 7, 11, 14, 18, and 23 days of storage. Monitored parameters were the same as described previously for pasteurized crab meat.

Statistical analyses were performed on chemical, sensory, and microbiological data by means of PC SAS (10). SAS GLM and Duncan’s multiple range test at the 0.05 level were used to determine any significant differences among days or months of storage and packaging materials.
RESULTS AND DISCUSSION

Crab meat pH values were significantly different (p < 0.05) for all treatments during the first six months in the following descending order: barrier pouch > aluminum can > non-barrier pouch > plastic can > steel can (Figure 1). Ammonia levels showed no consistent patterns with any packaging treatment during the first 10 months of the pasteurization study. Hunter L-values, an objective measurement of lightness and darkness, are shown in Figure 2. At zero time, following pasteurization, meats in plastic and aluminum cans and non-barrier pouches had higher L-values, indicating a lighter meat color, than product in steel cans (p < 0.05). At 4 months meat in plastic containers had higher L-values than meat stored in barrier pouches. Hunter a and b values and Stensby's WI index showed no consistent differences with time.

![Figure 1. Pasteurized crab meat pH levels following refrigerated storage in the five monitored containers.](image)

All treatments had low aerobic plate counts through 6 months of storage (Figure 3). Meat composited from plastic cans in the eighth month were microbiologically spoiled. However, plate counts from meat in steel cans, with the highest process F-value, were definitely less than the other treatments at the end of 8 months (p < 0.05). Meat collected from the plastic cans at 10 months had acceptable plate counts. The cause of the microbiological spoilage in meat sampled from plastic cans in the eighth month was not determined. Meat from barrier pouches had plate counts above $10^5$ CFU/g at the end of 10 months. Plate counts determined for non-barrier pouches and steel cans were less than other treatments following 10 months of storage (p < 0.05) (Figure 3).

Psychrotrophic levels in plastic cans increased rapidly between zero time and 2 months, leveled off, and decreased between 8 and 10 months (Figure 4). Aluminum cans had the lowest psychrotrophic levels.

Sensory odor analysis that included ammonia, sour, putrid, and crab odors showed no consistent differences among the treatments over the storage period. At zero time meat from barrier bags and steel cans had the least acceptable color (Figure 5). Product from
Figure 2. Hunter L-values of pasteurized crab meat following refrigerated storage in the five monitored containers.

Figure 3. Log of plate counts from pasteurized crab meat following refrigerated storage in the five monitored containers.

Barrier pouches received the lowest color acceptability ratings throughout the study. At 4 months meat from aluminum or plastic containers had better sensory color than meat from steel cans or barrier pouches (p < 0.05). Plastic and aluminum cans had the highest sensory color ratings at 6 months. The eighth month brought a change, with panel members indicating meat from steel and plastic containers had better color than product from aluminum cans and non-barrier pouches, in spite of definite microbiological spoilage.
Figure 4. Log of psychrotrophic plate counts from pasteurized crab meat following refrigerated storage in the five monitored containers.

Figure 5. Sensory color acceptability of pasteurized crab meat following refrigerated storage in the five monitored containers.

determined for meat from the plastic containers. At 10 months meat from aluminum or plastic containers had better sensory color scores than the other samples ($p < 0.05$).

Plastic cans contained meat that rated the best sensory appearance at zero time ($p < 0.05$) (Figure 6). Meat from steel cans and non-barrier pouches had a better appearance rating than meat from aluminum cans or barrier pouches ($p < 0.05$). Meat
Figure 6. Sensory appearance acceptability of pasteurized crab meat following refrigerated storage in the five monitored containers.

from barrier pouches received the worst appearance ratings throughout the study (p < 0.05). Plastic cans were rated definitely better than steel cans or barrier pouches in the sixth month (p < 0.05). There were no significant differences in appearance by the eighth month. At 10 months meat from aluminum or plastic containers had better appearance scores than the other samples (p < 0.05).

Figure 7. Log of plate counts from fresh crab meat stored in the four monitored containers at iced (32°F) or refrigerated (39.2°F) temperatures.
We determined microbiological quality of fresh picked meat by arbitrarily defining meat with plate counts under 100,000 CFU/g as good quality, meeting most state regulatory requirements for fresh picked crab meat (4). Meat with plate counts between 100,000 and 1,000,000 CFU/g was considered poor quality, but typical of many products found at the retail level. Plate counts above 1,000,000 CFU/g were considered to be microbiologically spoiled.

All iced samples maintained good microbiological quality through 7 days of storage (Figure 7). Saran®-over-wrapped meat had higher plate counts than Trigon ISPF packaging, which had greater bacterial numbers than Cryovac pouches, which in turn had greater plate counts than those determined for plastic cups (p < 0.05). Meat in plastic cups and Trigon ISPF trays maintained market quality for 11 days of storage, with plate counts of meat packed in traditional plastic cups determined to be significantly less than all other treatments on days 7 and 11 (p < 0.05). All samples were microbiologically spoiled by day 14 (Figure 7).

All refrigerated samples retained good microbiological quality through 3 days of storage at 39.2°F. Trigon ISPF packages had greater plate counts than the other treatments at three days (p < 0.05). Refrigerated plastic cups and Cryovac pouches maintained minimum market quality for more than 7 days of refrigerated storage (Figure 7). Trigon ISPF trays had definitely higher plate counts than Saran® over-wrapped samples which had greater bacterial numbers than meat in plastic cups or Cryovac pouches at 7 days. All refrigerated samples were spoiled microbiologically by day 11 (Figure 7). Meat packaged in refrigerated Cryovac permeable pouches had lower psychrotrophic plate counts than all other treatments on days 3 through 14 (p < 0.05) (Figure 8).

**Figure 8.** Log of psychrotrophic plate counts from fresh crab meat stored in the four monitored containers at iced (32°F) or refrigerated (39.2°F) temperatures.

Refrigerated crab meat held in trays overwrapped with Saran® had greater (p < 0.05) ammonia and pH levels than all other packaged meats on days 11 through 14 (Figures 9 and 10).
Figure 9. Ammonia concentrations determined from fresh crab meat stored in the four monitored containers at iced (32°F) or refrigerated (39.2°F) temperatures.

Figure 10. Levels of pH determined for fresh crab meat stored in the four monitored containers at iced (32°F) or refrigerated (39.2°F) temperatures.

Saran\textsuperscript{R} over-wrapped meat and meat stored in plastic cups were determined to have stronger sour odors than meat in Trigon ISPF trays on day 11 (p < 0.05) (Figure 11). Putrid odors were rated as greater in Saran\textsuperscript{R} over-wrapped trays than Cryovac pouches or Trigon ISPF trays at 11 days of iced storage (Figure 12). The panel found Trigon ISPF meat to have better color than meat held in plastic cups or Saran\textsuperscript{R} wrapped trays at 11 days of iced storage (p < 0.05) (Figure 13). Similar results were determined for appearance (Figure
Figure 11. Sour odor of fresh crab meat stored in the four monitored containers at iced (32°F) and refrigerated (39.2°F) temperatures.

Figure 12. Putrid odor of fresh crab meat stored in the four monitored containers at iced (32°F) or refrigerated (39.2°F) temperatures.

Iced storage (p < 0.05) (Figure 13). Similar results were determined for appearance (Figure 14). Refrigerated meat at 39.2°F did not show sensory differences similar to those determined for iced samples prior to microbiological spoilage.
Figure 13. Sensory color acceptability of fresh crab meat stored in the four monitored containers at iced (32°F) or refrigerated (39.2°F) temperatures.

Figure 14. Sensory appearance acceptability of fresh crab meat stored in the four monitored containers at iced (32°F) or refrigerated (39.2°F) temperatures.

CONCLUSIONS

At zero time, following pasteurization, meats in plastic and aluminum cans and non-barrier pouches were lighter in color than product in steel cans as determined by significantly higher L-values. At 4 months meat in plastic containers had higher L-values than meat pasteurized in barrier pouches. At 10 months meat from aluminum or plastic containers had significantly better sensory color and appearance scores than pasteurized meat from steel cans or barrier and non-barrier pouches.
The longest microbiological shelf life for fresh special stored at 32°F was 11 days in both plastic cups and ISPF permeable packaging. Iced meat packaged in ISPF had better sensory characteristics than meat held in plastic cups at 7 and 11 days of storage. Refrigerated fresh special packaged in plastic cups or non-barrier pouches had the longest microbiological shelf life, 7 days at 39.2°F when compared to Trigon ISPF and Saran® overwrapped trays. Sensory quality of meat held at 39.2°F was not improved by any investigated packaging.

REFERENCES


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APPLICATION AND EFFECTS OF LACTIC ACID AND CRYOPROTECTANTS ON THE STORAGE STABILITY OF FROZEN CRAB CORES AND CRAB MEAT

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INTRODUCTION

Fresh blue crab (Callinectes sapidus) meat is a highly perishable product with a limited shelf-life of up to 10 day. Since blue crabs are harvested seasonally with huge market gluts, industry has a continuing interest in expanding the marketing of crab meat beyond peak harvest. Such an extension of the processing and marketing of blue crab meat could lead to increased economic gains to all segments of the crab industry. Current methods of extending the storage of crabmeat involve pasteurization, sterilization, and freezing. All three methods, however, result in deteriorative changes in texture, appearance, flavor, and odor (1,3,10). Since fresh crabmeat currently represents the major method of marketing blue crabs while freezing results in the least deteriorative change in quality with storage, this study was designed to examine methods of extending the shelf-life of fresh and frozen blue crab meat and crab cores. The objectives were two-fold in that we wanted to determine the effects of lactic acid application on the storage stability of fresh crab cores and the effects of cryoprotectants on the storage stability of frozen crab meat.

METHODS

Sample Preparation: A local firm processed Atlantic Blue crabs (Callinectes sapidus) by steaming at 121° C (15 psi) for 12 min followed by cooling. Since crab cores could represent an intermediate product available for delayed picking during off-season or reduced harvest, cooked crabs were either fully picked to form processed crabmeat or debacked to create crab cores.
Part I: Application of lactic acid and cryoprotectants
Crab cores and picked crabmeat were vacuum infiltrated with a 3% aqueous solution of lactic acid for 10, 15, or 20 min or dipped for 10 or 20 min. Two cryoprotectants, sucrose and polydextrose were applied in aqueous solutions at concentrations of 10, 15, or 20% by vacuum infiltration and by dipping. The dipping procedures involved placing cores or picked crabmeat in solutions of lactic acid or cryoprotectants for 4 or 8 minutes, followed by draining for 2 min.

Vacuum Infiltration: Crab cores and picked meat were dipped into individual beakers containing solutions of lactic acid or cryoprotectants. The beakers were placed in the vacuum infiltrator (Nash Engineering Co., South Norwalk, CT) and the vacuum pressure allowed to reach 25 psi. The vacuum was immediately released and samples allowed to remain in the solutions for an additional 20 minutes prior to draining for 2 min. The effectiveness of the lactic acid and cryoprotectants in reaching the surface of the meat was measured by pH changes and sugar concentration, respectively. The pH was measured with a Fisher Scientific electrode (Fisher Accumet, Model 292) standardized against a pH 7.0 phosphate buffer. The concentration of cryoprotectants was measured by the phenol-sulfuric acid method for total carbohydrates (4) by measuring the absorbance at 490 nm against a standard curve using polydextrose or sucrose.

Part II: Effects of cryoprotectants on the storage stability of frozen crabmeat.
The second study was designed to compare the effectiveness of cryoprotectants, processing techniques, and storage methods on the chemical, physical, and sensory properties of crabmeat stored for up to eight months. Following the commercial processing of whole blue crabs, 1 lb aliquots of picked crabmeat were divided into the following treatments: (1) pasteurized; (2) untreated reference; (3) water; (4) polydextrose, 15% (wt/wt); (5) sucrose (7.5% wt/wt) + sorbitol (7.5% wt/wt) + tripolyphosphate, 0.5% (wt/wt). Treatments 3-5 were applied by dipping the crabmeat into their respective pre-chilled solutions (4° C) for 4 min and draining 10 min within a
refrigerated cooler. Following application of the treatments, samples were vacuum packaged as 1 lb units in low oxygen permeable Type B™ bags (W.R. Grace and Co., Duncan, SC), cryogenically frozen with liquid nitrogen (-23° C), and stored at -29° C until analyzed. The untreated reference sample was packaged similarly and stored at -65° C and used as a point of reference for chemical, physical, and sensory analyses. Samples designated as the pasteurized treatment were processed in 1 lb cans to an internal temperature of 85° C, cooled, and stored under refrigeration at 1.1° C until evaluated. Frozen samples were thawed under refrigeration (4° C) prior to evaluation at 0, 6, 12, 18, 24, 28, and 32 weeks of storage.

Chemical and Physical Measurements: Chemical indices of loss of quality consisted of measuring the 2-thiobarbituric acid number (8) for malonaldehyde formation and change in fatty acid composition as described by Sampugna, et al (9). Physical measurements consisted of texture, expressible moisture, and color. An Instron Universal Testing Machine (Model CS-1; Food Technology Corp, Rockville, MD) was used to measure shear force. Drip loss and expressible moisture were determined as described by Jaregui et al. (2) while color changes were measured with a Spectroguard Colorsystem (Model, 96, Pacific Scientific, Silver Spring, MD) using the Hunter L a b scale.

Sensory Analyses: Sensory evaluations were conducted by a trained panel. The trained panel consisted of 12 members using quantitative descriptive analysis (6) to characterize changes in appearance, aroma, flavor, and texture occurring during storage of crabmeat samples.

Statistical Analyses: All data were analyzed using a general linear model procedure (10) using a randomized complete block design with the entire study replicated two times.

RESULTS

The absorption of a 3% solution of lactic acid into crab cores and picked meat, via dipping or vacuum infiltration, is shown in figure 1. Significant differences (P<0.05) in pH were observed between crabmeat samples which were dipped and vacuum infiltrated. A comparison of the pH of crab cores and of picked
Fig. 1: Change in pH following vacuum infiltration (VI) and dipping of crab cores and crabmeat in lactic acid.

Fig. 2: Absorption of cryoprotectants following vacuum infiltration and dipping.
meat dipped or vacuum infiltrated for 8 minutes found that the 
dipping of cores did not allow for effective penetration of lactic 
acid into the crabmeat. The pH of picked meat was 
approximately 2.4 times lower than cores, whereas no 
significant differences were observed in pH values between 
picked meat which had been dipped or vacuum infiltrated for 8, 
10, 15, or 20 minutes. The absorption of polydextrose and 
sucrose followed a similar pattern to that observed for lactic 
acid (Fig 2). Significant differences in the concentration of 
cryoprotectants were observed between samples which had 
been treated with different concentrations of cryoprotectants. 
However, there were no differences in cryoprotectant 
concentration as a function of the processing times of 10 and 20 
min of either picked meat or vacuum infiltrated cores.

The relative effectiveness of the two methods in applying the 
lactic acid or the cryoprotectants supports the findings of other 
investigators (3,7) in demonstrating that without vacuum 
 injection or direct injection techniques, many applied additives 
may only have a surface-coating effect with very little of the 
chemical penetrating the interior tissues. Thus, to determine the 
effects of these additives in enhancing the storage stability of 
fresh crab cores or frozen crab meat, one has to be certain that 
the chemical is reaching the target tissue at a given level to be 
effective.

The effects of the treatments on the physical and chemical 
properties of crabmeat are shown in Table 1 with results 
representing an average over all sampling periods. Both drip 
loss and expressible moisture values were significantly higher 
for water treatments than the other treatments at all sampling 
periods. The mean drip loss of the sucrose/sorbitol/phosphate 
and polydextrose treated samples did not differ significantly 
from the untreated reference stored at a much lower 
temperature (-65°C). When drip loss and expressible moisture 
patterns were examined over the 32 week storage period, all 
samples showed increases in drip loss and expressible moisture 
values at week 12. The untreated reference, however, showed 
the greatest increase in expressible moisture at week 24.

Mean shear force values indicated that the water treatment had 
the highest mean shear force value, whereas no significant 
differences were observed between samples treated with
Table 1. The effects of the treatments on the mean physical and chemical characteristics of crabmeat.

<table>
<thead>
<tr>
<th>Analyses</th>
<th>Untreated Reference</th>
<th>Pasteurized</th>
<th>Water</th>
<th>Polydextrose</th>
<th>†Sucrose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical Tests</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drip Loss (%)**</td>
<td>26.49&lt;sup&gt;b&lt;/sup&gt;</td>
<td>23.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>29.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26.72&lt;sup&gt;b&lt;/sup&gt;</td>
<td>25.28&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Exp. Moisture (%)**</td>
<td>48.41&lt;sup&gt;b&lt;/sup&gt;</td>
<td>45.39&lt;sup&gt;c&lt;/sup&gt;</td>
<td>52.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>51.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>49.93&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Shear Force (Kg/cm)**</td>
<td>2.80&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.54&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.94&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total Energy(cm)</td>
<td>0.97</td>
<td>0.99</td>
<td>0.88</td>
<td>0.94</td>
<td>0.93</td>
</tr>
<tr>
<td>Total Energy/Shear Force*</td>
<td>0.41&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.40&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.27&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.32&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>0.34&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hunter &quot;L&quot;**</td>
<td>72.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>71.37&lt;sup&gt;b&lt;/sup&gt;</td>
<td>72.68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>72.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>73.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hunter &quot;a&quot;**</td>
<td>-0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.33&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>-0.57&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.62&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hunter &quot;b&quot;**</td>
<td>12.24&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.48&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.67&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.90&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>11.48&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td><strong>Chemical Tests</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Moisture (%)**</td>
<td>76.45&lt;sup&gt;b&lt;/sup&gt;</td>
<td>75.77&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>78.42&lt;sup&gt;a&lt;/sup&gt;</td>
<td>76.26&lt;sup&gt;b&lt;/sup&gt;</td>
<td>74.86&lt;sup&gt;c&lt;/sup&gt;</td>
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<tr>
<td>Protein (%)*</td>
<td>19.72&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.03&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>17.19&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>15.99&lt;sup&gt;c&lt;/sup&gt;</td>
<td>17.67&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>1.55</td>
<td>1.50</td>
<td>1.34</td>
<td>1.25</td>
<td>1.28</td>
</tr>
<tr>
<td>TBA (mg/kg)**</td>
<td>0.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.28&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.21&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.06&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.25&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means followed by the different letter in any given row were significantly different at .05 level (*) or highly significant at .01 level (**). †Sucrose/sorbitol/phosphate.

Table 2. Trained panel summary: The effects of the treatments on the mean sensory characteristics of crabmeat.

<table>
<thead>
<tr>
<th>Sensory Attribute</th>
<th>Untreated Reference</th>
<th>Pasteurized</th>
<th>Water</th>
<th>Polydextrose</th>
<th>†Sucrose</th>
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<tbody>
<tr>
<td><strong>Appearance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sheen**</td>
<td>5.00&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.65&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.58&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>6.64&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.00&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Grey/Blue**</td>
<td>3.51&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.62&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.49&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.08&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.79&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>Yellow/Green*</td>
<td>5.14</td>
<td>4.62&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.61&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.72&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.09&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Aroma</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh Crab**</td>
<td>4.64&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.56&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.49&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.15&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>5.46&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ammonia*</td>
<td>3.89&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>4.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.83&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.34&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.11&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sour**</td>
<td>2.95&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.62&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.89&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.69&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.57&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td><strong>Flavor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sweet**</td>
<td>4.99&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.16&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.15&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.44&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fresh Crab**</td>
<td>4.61&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>3.08&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.08&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.08&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sour**</td>
<td>3.71&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.54&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.26&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.70&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>2.18&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>Rancid**</td>
<td>3.12&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.98&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.93&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.34&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>2.16&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Texture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hardness</td>
<td>5.52</td>
<td>5.99</td>
<td>6.39</td>
<td>6.07</td>
<td>5.76</td>
</tr>
<tr>
<td>Toughness*</td>
<td>4.86&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.29&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.09&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.84&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Moisture Persistence**</td>
<td>6.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.42&lt;sup&gt;ac&lt;/sup&gt;</td>
<td>7.17&lt;sup&gt;d&lt;/sup&gt;</td>
<td>7.14&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total Intensity of Attributes**</td>
<td>5.11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.27&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.73&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.57&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means followed by different letters in any given row were significantly different at .05 level (*) or highly significant at .01 level; †Sucrose/sorbitol/phosphate.
cryoprotectants and the untreated reference. Examination of the total energy to shear force also revealed that the water treatment was more brittle (less deformable) than all the other treatments. By contrast, the pasteurized treatment was noted to be more rubbery and more deformable than all other treatments. The additional heat treatment resulting in additional protein denaturation may have been responsible for texture profile observed in the pasteurized sample.

The treatments appeared to have a significant impact on Hunter L, a and b values for white, red, and yellow colors. The pasteurized treatment had the darkest color (L values) whereas the polydextrose and sucrose/sorbitol/phosphate retained less red notes than the untreated reference, pasteurized, or water treatment. The pasteurized sample also had more blue color notes (b values) than all other treatments. All treatments became lighter at week 24 confirming moisture and drip loss data that moisture was being loss by all samples.

Examination of chemical data revealed that the treatments had a significant effect on TBA numbers. The polydextrose treatment had the lowest TBA values, whereas the untreated reference had the highest value with no significant differences observed between pasteurized, water, and sucrose/sorbitol/phosphate treatments. The treatments had no effect on the fatty acid composition in that the relative ratio of polyunsaturated fatty acids to saturated fatty acids did not differ over the course of the study.

Sensory Panel Evaluation: Table 2 shows the summary of the effects of the treatment on mean sensory attributes of crabmeat. Samples treated with polydextrose and sucrose/sorbitol/phosphate were rated highest in sheen, whereas the untreated reference sample was lowest. The pasteurized treatment showed highest values for grey/blue discolorations. Examination of the aroma profiles of treatments revealed that the polydextrose and sucrose-/sorbitol/phosphate samples retained more fresh crab aroma and less ammonia, whereas the untreated and water treatments contained more ammonia and less fresh crab aroma. The pasteurized treatment was observed to have more sour and ammonia aromas than all other treatments.
Treatments containing cryoprotectants were observed to have significantly higher scores for sweetness and fresh crab flavor than the untreated reference sample, pasteurized, or water treatment. The pasteurized treatment was observed to have the highest scores for sour and rancid notes followed by the untreated reference and water. Treatments containing the polydextrose and sucrose were equally and most effective in suppressing sour and rancid notes. Examination of texture profiles of the treatments revealed greatest moisture persistence in samples treated with the cryoprotectants with the pasteurized sample showing least. Though no significant differences in hardness were found between treatments, the water treatment had the toughest texture with no differences observed between all other treatments.

Examination of the total intensity of attributes (TIA) most closely associated with fresh crab flavor and aroma indicated that treatments containing the polydextrose and sucrose/sorbitol/phosphate were rated highest and equally effective in maintaining sensory attributes closest to fresh crabmeat. The pasteurized treatment was rated lowest followed by the water and untreated reference control.

Comparison of the data from trained panel evaluation of sensory attributes to chemical and physical measurements revealed several areas of agreement. Panel assessment of sheen and grey/blue discoloration agreed with Hunter L and b values showing that cryoprotectants had a positive effect on color. Expressible moisture, moisture persistence, and shear force values all indicate that as samples begin to lose moisture, the water treatment had significantly higher water losses and that this may have contributed to higher shear force values and toughness scores found by Instron measurements and trained panel scores, respectively.

CONCLUSIONS

The results from these studies indicate that the addition of the cryoprotectant, polydextrose and sucrose/sorbitol/phosphate significantly improved the sensory attributes of fresh crabmeat over an eight month period of frozen storage. Comparison of sensory data to chemical and physical measurements indicate improvements in moisture retention, texture, and possibly
decreased oxidation may be attributed to the addition of the cryoprotectants. Preliminary assessment of techniques to imbibe tissues and crab cores with the addition of lactic acid or cryoprotectants indicate that vacuum infiltration can be used to assure effective penetration of crab cores whereas either dipping or vacuum infiltration can be used to assure penetration of solutions into picked fresh crabment.

ACKNOWLEDGMENTS

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