Use of a Model Scale System for Recycling Spent Fishery Brines

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ABSTRACT

Fishing boat hold refrigeration brines become contaminated with organic fish material. Discarding these brines may cause environmental pollution and results in the loss of nutrient-rich fluids. Bench scale experiments determined that these brines could be recycled at least five times. Purified brines were free of microbial contamination and reached chemical equilibrium after its second reuse trial. The flavor and carcass quality of the fish stored in the recycled brine were not significantly different (p<0.05) from similar fish stored as controls.

Salt brines are often used as refrigerants, conveying fluids and washwaters during the processing steps of some fishing operations. These brines can become contaminated with blood, slime, pieces of flesh and entrails from the fish during use and are currently being disposed of after use. They are usually discarded directly to a receiving water body or into a waste treatment system. Both of these practices may be inadequate methods of waste management for the seafood industry. Direct discharge of this waste is a contrivention of environmental law while conventional effluent treatment systems may not be readily adapted to the variations in organic waste strength, salt concentration and flow volume found with these fishery effluents. In addition, the cost of installing and operating conventional sewage treatment systems may be prohibitive for most fish processing plants.

One way of reducing this fish processing waste treatment problem would be to develop and institute water conservation programs and to reuse waste waters where possible. The effluents would have to be renovated before reuse. This requirement could be achieved by using a closed loop recycling system. These systems take the waste water from a processing step, renovate it and then reuse the water in the same step without affecting the toxicological, sanitary or organoleptic quality of the product. This type of system has been used to recycle cherry processing brines (4), citron curing brines (6) and cucumber pickling brines (10,13). The purpose of this paper is to examine the potential value of using recycling systems for managing certain fishing industry brines.

MATERIALS AND METHODS

Experimental procedure

A model scale system similar to methods used to freeze tuna aboard the fishing vessel was used for these experiments. Here, 3.4 kg of freshly caught whole mackerel (Scomber scombrus) were placed in a stainless steel drum and flooded with 0.7 kg of 9.0% (w/v) sodium chloride (NaCl) brine and placed in cold storage to freeze. A 9% brine was used because it was similar to salt concentrations in brines used on fishing boats. Fish and brine were stored frozen for 7 d at -17.8°C. At the end of the storage period, the fish and brine were thawed and the fish separated from the brine. The used brine was renovated using a treatment system described in the next section. Renovated brine was reused up to five times.

Equipment description

An ultrafiltration-activated carbon (UF-AC) treatment system was used to renovate the brine before use. This system has been described elsewhere (21,22). The UF unit was an Amicon TCF 10 thin channel ultrafiltration apparatus lined with an Amicon PM 30 membrane (Amicon, Ltd., Danvers, MA). The operating conditions were: T = 37.8°C; P = 21,093 kg/m² using a nitrogen gas positive pressure; and pump speed = 6. The membrane was cleaned with 2 M NaCl after each trial, and then stored under distilled water until the next trial. The activated carbon column consisted of 25 g of 40-200 mesh granulated activated coconut charcoal (Fisher Scientific, Ltd., Rochester, NY) that was slurried in distilled water than poured into a 3.5 cm by 25 cm plexiglass column. Pyrex brand glass wool (Corning Glass, Ltd., Corning, NY) plugs were placed in the column before and after the activated carbon was placed in the column. The column was operated in a downflow mode with the full volume of the brine (minus 50 ml) being eluted through the column in 15 min. After each use, the column was flushed with 4% NaOH at 55 to 70°C, and then rinsed with distilled water.

Brine analysis

After each reuse trial, 50-ml grab samples were taken from untreated and treated brine and stored at 4°C. These samples were analysed within 24 h for microbial parameters and within 7 d for chemical parameters. The microbiological parameters included mesophilic aerobes, moderately halophilic mesophilic aerobes, psychrophilous, moderately halophilic psychrophilous and yeast and mold counts. The methods used for the analyses conformed to the procedures described by Speck (19). The treated brines were also screened for enterovirus contamination according to the methods of Rovozzo and Burke (15).

The chemical parameters were pH, turbidity, titratable acidity (TA), total Kjeldahl nitrogen (TKN), total sugars (TS), chemical oxygen demand (COD), total residue (TR), fixed residue (FR) and volatile matter...
Quality analyses

Raw fish quality and cooked fillet quality were evaluated following each storage trial. The mackerel was graded for physical appearance just before treatment and then promptly after the fish were removed from the brine following storage at -17.8°C for 7 d.

Raw fish quality characteristics such as appearance of gills, eyes and skin, odor, the presence of physical damage and belly firmness were evaluated using the 1978/79 TRF-FDA training school raw fish quality evaluation procedures. After evaluation, classifications for each fish characteristic were assigned a numerical value from one (excellent) to four (rejectable). The characteristic values were averaged for each trial, and the average value was used as an overall estimate of raw fish quality. Results within each trial were compared using the least squares method for one way analysis of variance (18).

Cooked fillet quality was determined for fresh mackerel fillets that had not been brine-stored, for fillets from mackerel stored in new brine and for fillets from mackerel stored in treated, reused brine. Fillets were taken from the fish and then stored frozen at -17.8°C before organoleptic grading. Frozen fillets were thawed and then prepared for evaluation by broiling them under an electric broiler for 4 min per side. These fillets were examined for differences in organoleptic quality parameters such as odor, appearance and flavor. A 10-member organoleptic evaluation panel used a nine-point hedonic rating scale to estimate the fillets’ quality. This method is more completely described elsewhere (2). The results compiled for each brine reuse trial were analysed using the least squares method for one way analysis of variance (18).

RESULTS AND DISCUSSION

Several criteria ought to be considered if a system is used to renovate contaminated fishery refrigeration brines for reuse. First, the treatment system should remove undesirable mineral and chemical components which could accumulate in the brine and contaminate the fish. Second, the treatment system must prevent growth of pathogenic and spoilage-causing organisms. Finally, fish stored in recycled brine should be as good or better in quality than fish handled by existing refrigeration methods. This study used these criteria to investigate the potential for renovating and then reusing contaminated fishery refrigeration brines.

Chemical parameters

Turbidity, pH and titratable acidity analytical results (Table 1) indicate that acid components and colloidal material were removed from spent brine by using the UF-AC treatment system. Although data for untreated brine were variable, the treated brine analytical results were at consistently low levels. The turbidity of the treated brine was less than 10 mg of SiO₂/L while TA was 0 mg/L and pH was 9.0. Similarly, visual observation showed that red coloring material was removed from the brine (data not shown).

COD (Fig. 1), TKN (Fig. 2) and TS (Fig. 3) concentrations were also reduced by this treatment. However, consistent low background levels of these three contaminants remained in the brine following treatment. The background level of TKN was 75 mg/L for reuse cycles two through five. Previous work (21,22) has indicated that free amino acids, small peptide molecules and other nitrogen-containing chemicals remained in the brine following treatment. The COD results showed that the UF-AC treatment system left small amounts of COD-causing chemicals in the brine. In this instance, the COD of the untreated brine was reduced from up to 20,000 mg/L to a background level of 750 mg/L in recycle trials two through five. The total sugar

| Cycle |
|---|---|---|---|---|---|
| | pH | Untreated | Treated | Untreated | Treated | Untreated | Treated |
| 1 | 6.4 | 10.8 | 540.0 | 12.5 | 600 | 0 |
| 2 | 6.7 | 11.5 | 395.0 | 5.0 | 235 | 0 |
| 3 | 7.3 | 10.7 | 110.0 | 5.0 | 200 | 0 |
| 4 | 7.7 | 9.8 | 180.0 | 5.0 | 200 | 0 |
| 5 | 6.8 | 9.8 | 440.0 | 7.5 | 400 | 0 |

Figure 1. Kjeldahl nitrogen analysis results for samples of untreated and treated brine that had been reused up to five times, following treatment with the ultrafiltration-activated carbon treatment system.
concentration was also reduced to approximately 20 mg/L where it remained constant in cycles two through five.

Although background concentrations of nitrogenous material, sugars and other COD-causing material remained in the treated brine, these substances appeared to level off at about constant levels after the second cycle of reuse and remained nearly so through the fifth cycle. These data suggest that the UF-AC treatment system can be used to renovate the brine through five cycles. It is possible that some undetected organic toxicants may be present or formed in the brine and were not removed by the treatment system. These toxicants could contaminate fish subsequently cooled by the brine. Further research would be required to determine the extent, if any, of such a problem.

The amount of nitrogenous material, sugar and other COD-causing material left in renovated liquids may produce beneficial effects for the product. By maintaining background levels of a component in an effluent, the amount of the component that may be removed from the product by the process fluid could be limited. This effect could lead to improved organoleptic quality and enhanced nutritional status when compared to products handled by existing processing methods (11,14). Improvement in product quality by reusing processing fluids has been noted in the preservation of sweet cherries (4) and in cucumber pickling (8,10).

Investigations on the nutritional status of food processed in reused fluids have not been previously undertaken. They were also beyond the scope of this study. The effect of reusing brines with residual contaminant concentrations on the fish fillet organoleptic quality and raw fish quality was part of this study. These results are discussed later in this paper.

TR and FR changes within each experiment present interesting results. Figure 4 shows that the FR and TR concentrations of the untreated and treated brine were lower than the FR concentrations of the brine before use. These results suggest that the ash material could be binding to both the organic matter of the fish and the organic contaminants in the brine. When the fish were removed from the brine, the ash material that was bound to the fish was also removed. This effect would result in the FR reduction from the treated brine with the make-up salt added, to the untreated brine concentration in each experiment. A similar FR concentration reduction would also occur when the waste organic matter was removed during the treatment process. The residue that was removed during the treatment should be added back to the brine if the brine is to be reused. Thus make-up salt was added to the brine after each recycling loop. This result was similar to findings for the recycling of citron curing brines (6).

Figure 2. COD analysis results for samples of untreated and treated brine that had been reused up to five times, following treatment with the ultrafiltration-activated carbon treatment system.

Figure 3. Total sugar analysis results for samples of untreated and treated brine that had been reused up to five times, following treatment with the ultrafiltration activated carbon treatment system.

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Microbial parameters

The microbial data (Table 2) indicate that the UF-AC treatment system cleansed the brine before each reuse loop. Before treatment, the bacterial and yeast and mold counts were variable and high but following treatment the microbial counts were <10 for all reuse experiments. These data suggest that further contamination of the liquid would have to originate from the fish added to the brine during the recycling steps.

Table 2 also indicates that enteroviruses were not present in the renovated brine. In addition, several researchers have shown that marine and salt waters reduce the infectivity of polio virus (1), enterovirus (16) and other viruses (9, 17). Furthermore, alkaline pH values may also inhibit the infectivity and the integrity of enteroviruses (16). Renovated refrigeration brine has an alkaline pH. Thus refrigeration brines may be a poor environment for enteroviruses to exist in.

Raw fish and organoleptic quality

Raw fish quality. Figure 5 shows that raw fish quality was not changed by reusing renovated brines through at least five recycling trials. There was no significant difference (p<0.05) in samples of fish taken from fish stored in renovated brine, fish held in new brine and fresh fish examined before treatment.

Organoleptic quality. If a refrigeration brine is to be recycled in a closed loop system, the reused brine should not degrade the flavor, odor or appearance of fillets from fish stored in the brine. The product quality should remain the same or improve when compared to fish handled by traditional methods. If the quality is lowered, then recycled brines would probably not be used. The effect of brine recycling was examined on fillet appearance, odor and flavor.

The appearance grades of the cooked fillets (Fig. 6) indicate that fillets from fish stored in reused brine looked statistically (p<0.05) the same as or better than fillets taken from fish stored in new brine and fresh fish fillets. Fillet appearance was rated as acceptable to good for all test conditions.

In one instance (cycle 5), the brine-stored fish fillet appearance ratings were statistically higher (2.5 units higher) than the fresh fish fillet rating. The results of the two brine-stored samples were statistically the same. There were no
trends to indicate that this phenomenon might occur. Such results may have been due to sample variability.

The odor rating results (Fig. 7) and the flavor rating results (Fig. 8) for the fillet samples were similar in trend to the appearance results. That is, there was no significant difference (p<0.05) amongst the ratings for odor or flavor of the fresh frozen fillets, fillets from fish stored in new brine and fillets from fish stored in used brine through five cycles of brine reuse. Fillet odor and flavor were rated as acceptable to good for all test conditions. Experimentally,

the fish could be stored in brine that was recycled at least five times without adversely affecting the appearance, odor or flavor of the cooked fish fillets.

**CONCLUSION**

An ultrafiltration-activated carbon (UF-AC) treatment system was used to renovate brines from a model scale-sized fishery refrigeration system. The renovated brine was reused five times in a closed loop recycling system. The chemical, microbial and fish quality results showed that the brine could be reused five times without affecting the quality of the fish being stored in the brine.
REFERENCES


