Changes in Selected Chemical Quality Characteristics of Channel Catfish Frame Mince During Chill and Frozen Storage

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ABSTRACT: Changes in total volatile base nitrogen (TVBN), pH, salt soluble protein (SSP), moisture content, and expressible moisture of channel catfish frame mince during storage at −20, 0, and 5 °C were investigated. Refined mince was either unwashed or washed twice, with mince designated for frozen storage mixed with cryoprotectant. TVBN increased during refrigerated storage, while SSP decreased during frozen storage. Expressible moisture increased during frozen storage but not during refrigeration storage temperatures. Moisture content and pH of mince did not change during storage. Results indicate that mince should be stored for no longer than 3 d at 0 or 5 °C to maintain optimal quality. Frozen mince with cryoprotectant would remain acceptable for at least 3 months at −20 °C.

Key Words: catfish, mince, quality, surimi, shelf life

Introduction

FISH FRAME MINCE HAS SEVERAL HANDLING AND STORAGE problems (Regenstein and Regenstein 1991). Undesirable deterioration of fish muscle quality continues postmortem during processing and storage. Quality changes of fish muscle are normally due to autolytic chemical reactions, microbial proliferation, and physical property alterations that consequently cause poor functionality of end products (Cheng and others 1979; Scott and others 1988) and reduce shelf life (Huss 1988).

Processed channel catfish (*Ictalurus punctatus*) sold in 1996 totaled 9433 metric tons (NASS 1996). The feasibility of using catfish frame mince to manufacture value-added seafood products has been assessed (McAlpin 1993). Minced meat recovered from filleted catfish frames yields 50% to 75% of the frames total weight, amounting to 55% live catfish weight prior to filleting (Liu 1992; Hoke 1993). Past research has investigated the effect of food grade antioxidants on storage quality of unwashed catfish frame mince and surimi (Hoke 1993), the effect of increasing the number of wash cycles on color and functional properties of catfish frame surimi (Liu 1992), and changes in initial quantity and quality of frozen catfish frame mince (Chou 1993).

Ideally, minced muscle should be separated from catfish frames immediately after filleting. When not possible, specified storage times of catfish frames at different temperatures should be followed (Suvanich and Marshall 1998). Catfish frame mince is an intermediate product in the manufacture of surimi-based foods; thus, processors may desire flexibility in limited storage of mince prior to further processing. The impact of different storage times and temperatures on chemical quality attributes of catfish frame mince has not been reported. Therefore, the present study describes work that used selected chemical parameters to assess quality changes of unwashed and washed catfish frame mince stored at 3 different temperatures (−20, 0, and 5 °C). Each temperature mimicked common commercial conditions used for transportation, storage, or processing. Results of this research will be used to make storage time recommendations at the 3 temperatures to maintain optimal mince quality.

Results and Discussion

Recovery of catfish frame mince

After passing filleted catfish frames through the Bibun deboner, the average percent recovery of catfish frame mince from the duplicate processing experiments was calculated step-by-step from total weight (1760 kg) of filleted frames (Table 1). Results indicated that mince yield was 57.4% based on the total weight of filleted frames. Previous studies by Chou (1993) reported the average yields of catfish frame mince from Baader (1.3-mm drum perforation) and Paoli deboning machines were approximately 66.1% and 71.0%. However, the present yield was similar to those (50% to 60%) reported by Kim and others (1996) using a NDX 13 Bibun deboning machine.

Mince yield varies with species and other factors such as origin, maturity, size, storage conditions, and treatment before mincing (Hastings 1989). Yields also can vary due to the different types of deboners, different perforation sizes, belt speed, and belt tension on the same type of deboner. The Bibun and Baader deboners are belt-and-drum-type machines, while the Paoli is a drum-type deboner machine (Chou 1993). The major differences are a perforated drum and flexible tensioning belt compared to a cylinder drum and breaker bar (Adu and others 1983; Lee 1986; Field 1988). Lower recovered yields than the present study have been reported for different species using belt-and-drum deboners (Aguilar 1986; Lee and others 1990; Lin 1992).

Washing minced fish muscle improves color and sensory properties of final products (Adu and others 1983; Lin 1992; Liu

Table 1—Percent yields (w/w) of catfish frame mince following deboning, straining, washing, and dewatering processes

Process	Process yield (%)	Overall yield (%)
Deboning	57.4	57.4
Straining of unwashed mince	93.4	53.6
2-cycle-washing and straining	84.0	48.2
Dewatering by screw pressing	55.1	31.6

1992; Chou 1993; Hoke 1993). Table 1 shows that 84% mince was recovered after 2 wash cycles and straining. Chou (1993) recovered 75% catfish frame mince after one wash cycle. Chou (1993) used a Baader deboning machine with 1.3 mm perforation size drum that resulted in fine and pasty mince, a 1 to 4 ratio of mince to water for washing, and a centrifugal dewatering method. In the present study, we used a larger particle sized mince, a 1 to 3 ratio of mince to water for washing, and a screw press for dewatering. These processing differences may explain the yield differences between the two studies.

Table 2—Proximate analysis of unwashed and washed catfish frame mince with or without cryoprotectant

	Proximate analysis (%)			
Wash cycle	Moisture	Protein	Fat	Ash
Unwashed	70.3[c]	12.2[a]	16.5[a]	0.8[a]
Unwashed with cryoprotectant	64.2[d]	10.4[a]	17.0[a]	0.9[a]
Washed	85.3[a]	12.1[a]	2.3[b]	0.3[b]
Washed with cryoprotectant	79.0[b]	11.1[a]	2.6[b]	0.5[b]

[a-d] Means in a column followed by the same letter are not significantly different ($p > 0.05$).

Proximate analysis

Proximate analysis results of unwashed and washed frame mince are summarized in Table 2. Washed mince had lower ($P < 0.05$) levels of fat and ash and increased ($P < 0.05$) moisture content compared to unwashed mince. The level of crude protein remained unchanged ($P > 0.05$). Fat content decreased after washing because it floated to the surface and was removed. Other substances removed during washing include blood, pigments, odors, enzymes, mucus, and some water-soluble proteins (Miyauchi and others 1973; Okada and others 1973; Lee 1984; Babbitt 1986; Chou 1993; Hoke 1993). Reduction of fat content from washing may result in other composition changes because values were calculated on a total sample weight basis. However, the present study showed that there were no changes in protein content of catfish frame mince after washing likely due to a stoichiometric replacement of fat with water (Table 2). This finding was similar to that found by Adu and others (1983), who reported that amino acid composition and protein efficiency ratio of minced rockfish flesh did not change after washing. Decrease in ash content in frame mince after washing may be due to removal of water-soluble mineral constituents. Mince blended with cryoprotectant was lower ($P < 0.05$) in moisture content than unblended mince (Table 2), likely because of an increase in total solids. Overall, present proximate analysis results were very similar to those reported earlier for catfish frame mince (Liu 1992; Chou 1993; Hoke 1993).

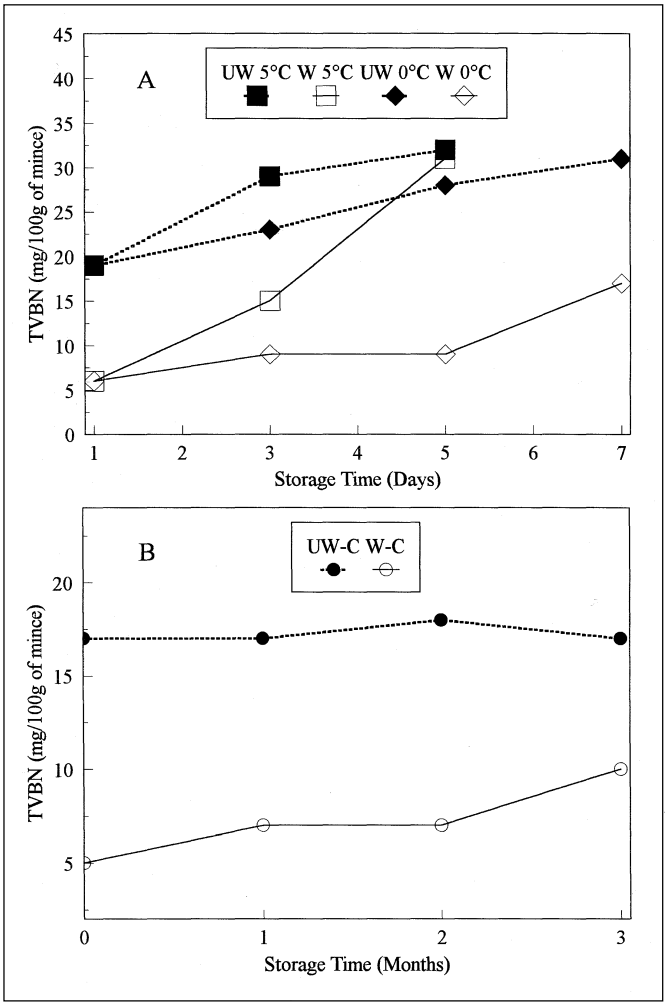

Figure 1—Total volatile base-nitrogen of catfish frame mince during storage at 5 and 0 °C (A) and –20 °C (B). UW = unwashed mince. W = washed mince. UW-C = unwashed mince with cryoprotectant. W-C = washed mince with cryoprotectant.

Change in total volatile base nitrogen (TVBN)

Initial TVBN values of unwashed mince was higher ($P < 0.05$) than that of washed mince regardless of added cryoprotectant (Fig. 1A and B). Lower TVBN values in washed frame mince could have resulted from removal of free amino acids, sarcoplasmic protein, or N-containing compounds of nonprotein nature during washing. Low molecular weight nonprotein nitrogen fractions are water soluble and range from 9% to 18% of the total nitrogen in fish (Huss 1988).

During storage at 5 °C, TVBN of both unwashed and washed frame mince progressively increased ($P < 0.05$) reaching 30 mg/100 g by 5 d storage, which coincided with presence of strong spoiled odor (Fig. 1A). At 0 °C, TVBN of unwashed frame mince gradually increased ($P < 0.05$) to 30 mg/100 g at 7 d, while TVBN of washed frame mince was 17.5 mg/100 g (Fig. 1A). The lower TVBN number in washed frame mince after spoilage was due to lower initial TVBN after washing. Initial TVBN of both frozen unwashed frame mince and surimi were 17.0 and 5.0 mg/100 g, respectively, which remained unchanged ($P > 0.05$) during storage at −20 °C (Fig. 1B). These results indicated that TVBN increases in unwashed catfish frame mince during storage at 5 and 0 °C were likely due to bacterial decomposition. TVBN values for washed mince stored at 0 °C were similar to those found with frozen mince, indicating the importance of washing to maintain mince quality.

Connell (1975) and Sikorski (1990) suggested levels of 30 mg TVBN/100 g in iced cold-water fish as the upper limit of acceptable freshness. However, Al-Kahtani and others (1996) reported lower levels of TVBN in warm-water tilapia (19.5 mg/100 g) and Spanish mackerel (25.2 mg/100 g) at rejection. Bennour and others (1991) reported that the TVBN values of several types of mackerel fish varied from 22.2 to 23.1 mg/100 g at different rejection times. The present study with warm-water catfish found that TVBN level of washed mince at 0 °C did not reach 30 mg/100 g when offensive odor was noticed. These results suggest that TVBN may be a poor indicator of catfish frame mince quality using previous criteria.

Change in pH

Changes in pH can affect the properties of connective tissue (Sikorski 1990). In addition, pH affects the denaturation rate of

myofibrillar proteins, which are important in gel-forming ability of minced fish (Matsumoto and Noguchi 1992). Myofibrillar proteins are unstable and rapidly lose their ATPase activity (an indicator of gel-forming ability) at a pH below 6.5 (Matsumoto and Noguchi 1992). The initial pH of washed catfish frame mince without cryoprotectant (7.2) was higher ($P < 0.05$) than that of unwashed mince without cryoprotectant (6.7) (Fig. 2A). Addition of cryoprotectant raised initial pH slightly ($P > 0.05$) because of the alkaline polyphosphate components in the cryoprotectant (Fig. 2B). Mince pH was higher than previously reported for either catfish frames (6.9) (Suvanich and Marshall 1998) or catfish fillets (6.6) (Silva and others 1993). Rodger and others (1980) similarly found that cod frame mince had higher pH values than cod fillet mince. Higher pH of washed frame mince compared to that of unwashed frame mince may be due to removal of free fatty acids, free acidic amino acids, lactic acid, or other water-soluble acidic substances. In addition, Chou (1993) indicated that higher pH values of catfish frame mince after washing could result from addition of high pH wash water, which was 7.8 in the present study.

Generally, pH profiles of both unwashed and washed catfish frame mince were very similar, with no significant changes ($P > 0.05$) occurring during storage at 5, 0, and −20 °C (Fig. 2A and B). Decomposition products such as volatile bases could lead to a pH rise during storage. Bennour and others (1991) reported less than one unit increase in pH of mackerel (*Scomber scombrus*) during storage on ice. Small change in pH of west-African marine fish during iced storage also was reported by Amu and Disney (1973). Rodger and others (1980) found changes in pH of minced cod during storage. They explained that declining pH values during early storage was due to formation of lactic acid from glycogen; whereas, rising pH later during storage was due to formation of dimethylamine (DMA) from trimethylamine oxide (TMAO). These changes in pH could affect connective tissue properties (Love 1980) and cause loss of myofibrillar protein solubility (Rodger and others 1980). Present results suggest that these possibilities would be negligible in catfish frame mince because pH was stable during storage.

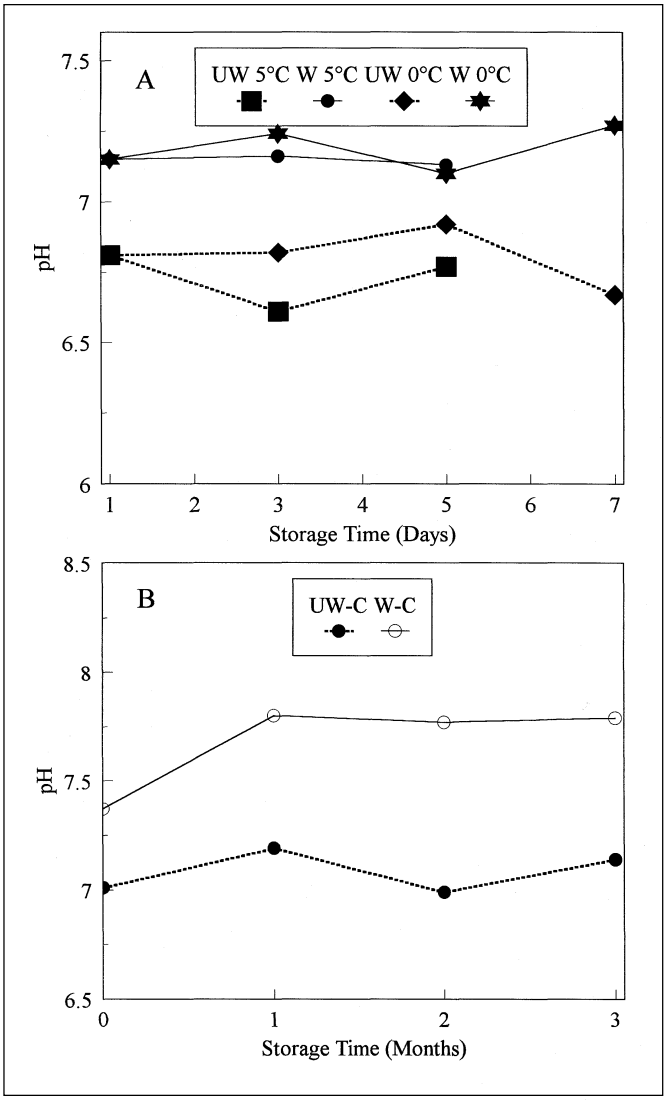

Figure 2—Change in pH of catfish frame mince during storage at 5 and 0 °C (A) and –20 °C (B). UW = unwashed mince. W = washed mince. UW-C = unwashed mince with cryoprotectant. W-C = washed mince with cryoprotectant.

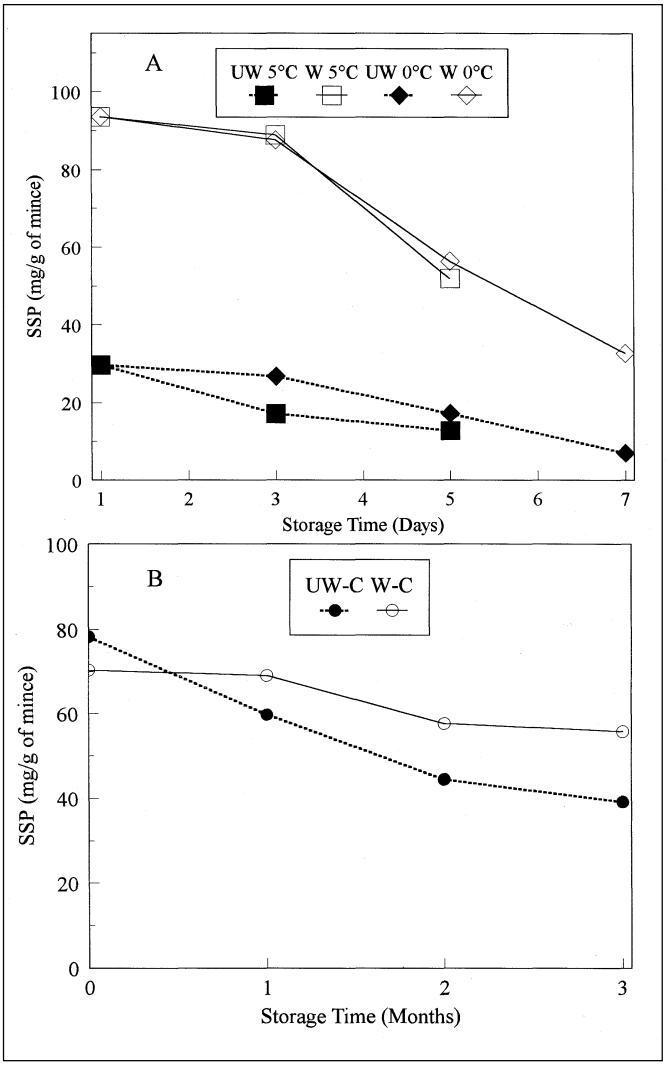

Figure 3—Salt soluble protein (SSP) of catfish frame mince during storage at 5 and 0 °C (A) and –20 °C (B). UW = unwashed mince. W = washed mince. UW-C = unwashed mince with cryoprotectant. W-C = washed mince with cryoprotectant.

Change in salt soluble protein (SSP)

SSP in nonfrozen unwashed frame mince (30 mg/g) was lower ($P < 0.05$) than in nonfrozen washed frame mince (95 mg/g) (Fig. 3A). Sarcoplasmic proteins are soluble in water and in dilute salt solution and generally comprise 20% to 25% of total fish muscle proteins (Sikorski and others 1994). Removal of sarcoplasmic proteins by washing increases the proportion of myofibrillar proteins or SSP in minced fish. Therefore, SSP values in unwashed frame mince were lower than in washed frame mince. Fig. 3B shows similar ($P > 0.05$) SSP levels in frozen unwashed (80 mg/g) and washed (70 mg/g) frame mince mixed with cryoprotectant. Cryoprotective agents, such as sucrose and sorbitol, can interfere with the SSP spectrophotoscopic method by causing turbidity, which can lead to artificially high SSP content (MFRD 1987). The high SSP value for unwashed mince with cryoprotectant may be due to such interference.

SSP levels of all mince samples decreased ($P < 0.05$) during storage at 5, 0, and −20 °C (Fig. 3). Enzymatic protein denaturation could have caused the reduction of SSP during storage. During storage of mackerel and amberfish, actomyosin denatures at a rate that declines with declining storage temperature (Jiang and others 1985; Sikorski 1990). Catfish frame mince SSP content and water-holding capacity were highly correlated ($r = -0.98$), confirming findings of Cheng and others (1979). The present study indicated that long storage time and high temperature contributed to the loss of SSP in both unwashed and washed frame mince. This loss could play an important role in reducing gel-forming ability of catfish frame mince to make surimi-based products.

Change in moisture content

Moisture content is a determinative indicator of surimi quality (Lanier and Lee 1992). Although screw press dewatering removed excess water from the washed frame mince, its moisture content (83.7%) was still higher ($P < 0.05$) than that of the unwashed mince (69.7%) (Fig. 4A). It is possible that removal of fat and water-soluble constituents, such as blood, pigments, proteins, and salts, by washing resulted in increased hydration of the mince meat (Lin 1992). Moisture content of unfrozen mince was higher ($P < 0.05$) than that of frozen mince due to addition of the cryoprotectant to the latter (Fig. 4B). There were no changes ($P > 0.05$) in moisture content of the minces during storage at 5, 0, and −20 °C.

Change in expressible moisture

Fig. 5 shows that unwashed mince had higher ($P < 0.05$) ex-

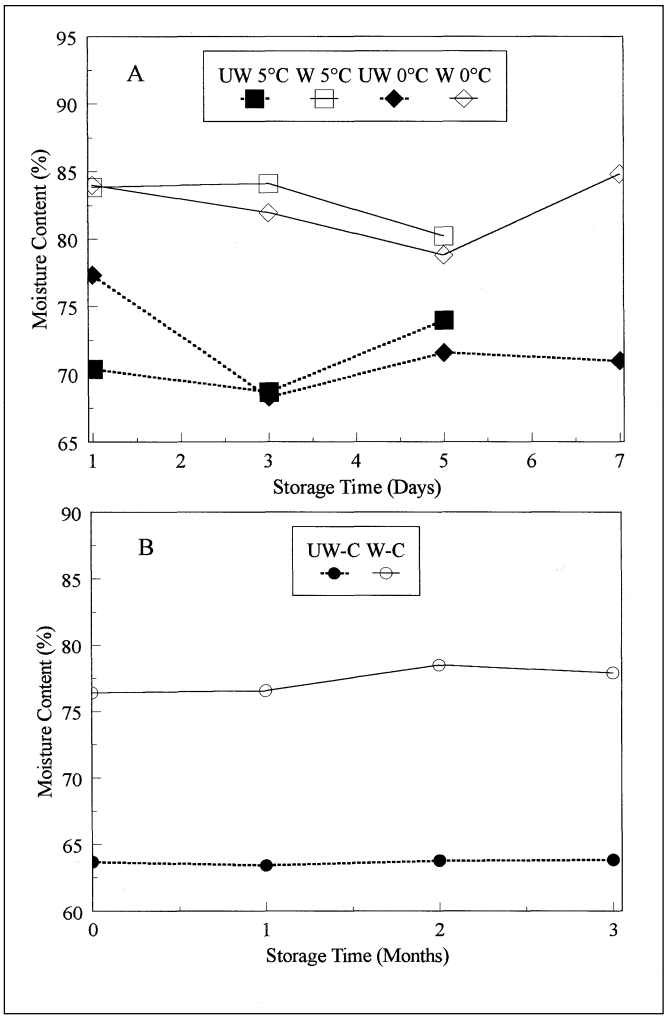

Figure 4—Moisture content of catfish frame mince and surimi during storage at 5 and 0 °C (A) and –20 °C (B). UW = unwashed mince. W = washed mince. UW-C = unwashed mince with cryoprotectant. W-C = washed mince with cryoprotectant.

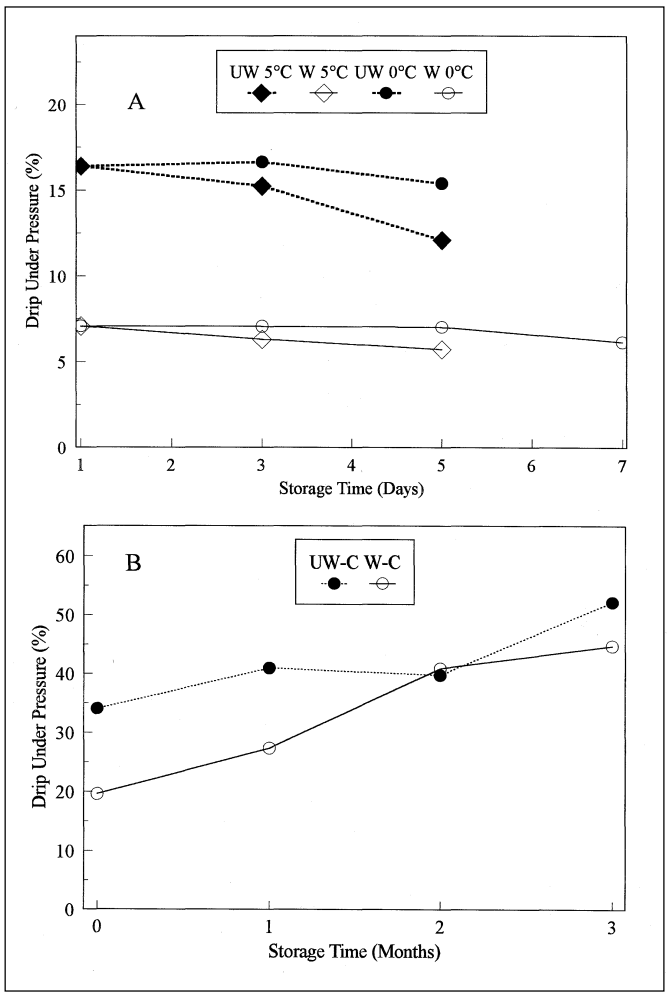

Figure 5—Expressible moisture (drip under pressure) of catfish frame mince during storage at 5 and 0 °C (A) and –20 °C (B). UW = unwashed mince. W = washed mince. UW-C = unwashed mince with cryoprotectant. W-C = washed mince with cryoprotectant.

pressible moisture than washed mince, indicating superior water-holding capacity of washed catfish frame mince. Water-holding capacity is directly correlated to myofibrillar protein content (Smith 1987). In addition, water-holding capacity of fish mince is directly correlated with gel product quality (Honikel and Hamm 1994). Gels prepared from unwashed catfish frame mince have higher expressible moisture values, which indicates lower water-holding capacity, than gels prepared from washed mince (Liu 1992).

Expressible moisture of both unwashed and washed mince did not change ($P > 0.05$) during storage at 5 and 0 °C (Fig. 5A), but increased ($P < 0.05$) during frozen storage (Fig. 5B). The increase in expressible moisture of mince during frozen storage may have been due to a change in microstructure of myofibrillar proteins from a continuous filamentous matrix to a globular matrix (Smith 1987). Cheng and others (1979) also stated that the loss of water-holding capacity of tissues during frozen storage was correlated with a decrease in myofibrillar protein solubility. Decreases in water-holding capacity leads to increased expressible moisture and protein denaturation (Reddy and Srikar 1991).

Expressible moisture of catfish frame mince was correlated with salt soluble protein content ($r = -0.98$). The amount of expressible moisture generally reflects the extent of protein denaturation resulting from surface dehydration, ice crystal formation, and cell rupture (Mishara and Srikar 1989).

Conclusion

DECREASED QUALITY OF UNWASHED AND WASHED CATFISH frame mince during storage at different temperatures coincided with increased TVBN, expressible moisture, and decreased SSP. Refrigerated storage of mince at 5 °C or 0 °C should not exceed 3 d; however, frozen storage (−20 °C) can increase storage life to at least 3 mo. Raw material quality as well as storage, processing, distribution times, and temperatures are important factors related to final product quality. Results from the present study can be used to delineate storage times of catfish frame mince at 5, 0, and −20 °C. Optimization of product transport, storage, and processing times will hopefully ensure product quality and wholesomeness, new high quality products, wider markets, and greater returns for the catfish processing industry.

Materials and Methods

Preparation of catfish frame mince

For each of 2 replicates, 1760 kg of channel catfish frames (deheaded, eviscerated, and filleted carcasses) were transported on ice from a commercial catfish processor to the Mississippi State University/National Marine Fisheries Service Experimental Seafood Processing Laboratory in Pascagoula, Miss., U.S.A. Upon receipt, frames were held in iceboxes (2.5 ± 0.5 °C) until used (< 48 h postmortem).

Frames were weighed and attached residual viscera was removed prior to passage through a deboner (Model DMM15, Bibun Machine Construction Co. Ltd., Japan) having a 5-mm diameter perforated drum. Frame mince was collected into containers, weighed, covered, and held on ice until further processed. One-half the mince was unwashed, while the other half was washed with 0 °C ice water (1:9 ice:water, w/w) in the ratio of 1 part mince to 3 parts ice water (w/w) in a wash tank. The slurry was gently agitated mechanically for 3 min, settled for 15 min, then pumped to a rotary screen rinser (Model F32LW, Bibun) for partial draining. Mince was washed twice to remove fat, blood, and other water-soluble substances. Both unwashed and washed minces were passed through a strainer (Model RE 120, Bibun) to remove residual pieces of bone and skin. The strained washed mince was passed through a screw press (Model YS200, Bibun) to remove excessive water to reach approximately 82% moisture content.

A cryoprotectant consisting of 4% (w/w) sucrose (ADM Food Additives Division, Decatur, Ill., U.S.A.), 4% (w/w) Neosorb sorbitol (Roquette America, Keokuk, Iowa, U.S.A.), and 0.3% (w/w) Nutrifos L-50 polyphosphate, a blend of tetrasodium pyrophosphate and sodium tripolyphosphate (Monsanto, St. Louis, Mo., U.S.A.) was mixed with both unwashed and washed minces designated for frozen storage. Stabilized minces were then packed (2 kg per bag) in 0.069-mm high-density polyethylene, heavy-duty Ziploc™ freezer bags (Dow Chemical, Indianapolis, Ind., U.S.A.) and frozen at −20 °C in a double-contact plate freezer (Dole Freezer-CEL, Model 2735-6A, Dole Refrigerating, Lewisburg, Tenn., U.S.A.) for 2.5 ± 0.5 h. Frozen frame mince was placed in ice chests for transportation.

Unfrozen mince without cryoprotectant was packed similarly and placed in ice chests surrounded by ice. All frame mince samples were transported for 4.5 ± 0.5 h to the Ammerman-Hearnsberger Food Processing Pilot Plant, Mississippi State University, Mississippi State, Miss., U.S.A. Upon arrival, sample bags were stored at −20, 0, or 5 °C in walk-in units. Periodically, 2 bags of each type of mince were randomly removed from each storage unit and evaluated for quality every month for samples stored at −20 °C for 3 mo and every 2 d for those stored at 0 and 5 °C until they were considered spoiled by presence of offensive odor.

Proximate analysis

The Mississippi State Chemical Laboratory was contracted to measure, crude protein, crude fat, and crude ash of unwashed and washed mince using AOAC (1994) methods.

Measurement of total volatile base nitrogen (TVBN)

Approximately 50 g mince was homogenized using a biohomogenizer (Model 133/1281-0, 2-speed, Biospec Products Inc., Bartlesville, Okla., U.S.A.) at high speed with 100 mL 7.5% aqueous trichloroacetic acid solution (Fisher Scientific, Pittsburgh, Penn., U.S.A.) for 1 min. The mixture was centrifuged in a Sorvall RC-28S centrifuge (DuPont, Wilmington, Del., U.S.A.) at 400 × *g* for 5 min and then filtered through a Buchner funnel using Whatman No. 3 filter paper (Whatman Int. Ltd., Mildstone, England). Steam entrainment was performed using 25 mL filtrate and 6 mL 10% NaOH (Sigma Chemical, St. Louis, Mo., U.S.A.) in a Kjeldahl-type distillation unit. Distillation was continued until a final volume of 50 mL (sample + steam condensate) was obtained in a 125-mL Erlenmeyer flask containing 10 mL of 4% boric acid with methyl red-bromocresol green indicator (Fisher). The distilled TVBN was titrated with 0.02 N (v/v) sulfuric acid solution (Sigma) until complete neutralization was obtained. TVBN content was expressed as mg/100g of frame mince as described by Malle and Poumeyrol (1989).

Measurement of pH

Five grams of catfish frame mince was homogenized (Biospec) at high speed for 1 min with 45 mL of deionized water in an 80-mL beaker. Homogenate pH was measured using a standardized portable pH meter (Acumet 1001, Fisher) as modi-

fied from the method of Scott and others (1988).

Measurement of salt soluble protein

Salt soluble protein (SSP) was extracted from one part mince with 20 parts 5% NaCl solution (Sigma). After homogenizing with a biohomogenizer (Biospec) at high speed for 1 min, the homogenate was centrifuged in a Sorvall RC-28S centrifuge (DuPont) at 7500 × *g* for 30 min (Ciarlo and others 1985). Protein concentration of the supernatant was determined using a micro-protein determination kit (Sigma Diagnostics Procedure No. 690) with absorbance read at 750 nm with a UV/VIS spectrophotometer (Lambda 3B, Model No. C618-0437, Perkin Elmer, Norwalk, Conn., U.S.A.). SSP was determined using a standard curve of a protein standard (Sigma) concentration versus absorbance values at 750 nm and expressed as mg/g of mince (Jiang and others 1987).

Measurement of expressible moisture

Mince cylinders (1 cm × 1 cm) were weighed (A), placed between 2 pieces of weighed Whatman No. 42 filter paper, and put on a Pyrex watch glass. Initial load of 500 g was applied on the top of the sample for 5 min, followed with another 500 g loading for an additional 20 min. After pressing with the loads, samples were weighed (B). The drip under pressure (amount of expressible moisture) was determined as (A) - (B) and calculated against sample weight (A) as a percentage (NFI 1991).

Statistical analysis

A split plot arrangement of treatments in a randomized complete block design was used with 2 replicate experiments. Each storage temperature was the whole plot factor, with the combination of treatments (unwashed and washed mince) and storage times as the split plot factors. General linear model, correlation analysis, and comparison of least significant different means (used for variables that were measured) for time and temperature were conducted using SAS (1988). Means were separated using the least significant difference test at 0.05 probability level (Dowdy and Wearden 1991; SAS 1988).

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MS 1999-0322 received 3/15/99; revised 6/3/99; acceptd 8/9/99.

This paper has been approved for publication as manuscriptnumber J-9477 of the Mississippi Agricultural and Forestry Experiment Station. Support for this project was provided by a USDA Special Grant Number 91-34231 and by the Mississippi Agricultural and Forestry Experiment Station under project MIS-0869. The authors thank Dr. Richard Podolak, Jan Gooch, and Tommy Schultz for help in mince processing and thank Dr. Patrick Gerard for statistical assistance. We thank Roquette America and Monsanto for providing gifts of Neosorb and Nutrifos L-50, respectively.

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