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Preface

The purpose of the workshop is to provide a combination of timely and pertinent topics of interest to processors and others associated with farm-raised catfish. If you should have comments and/or suggestions for future workshops, please refer them to

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Your input is necessary if we are to provide a program that meets your needs. Please feel free to contact us. If you need additional information on any subject presented, you may contact the speaker directly (see page 17 for speakers' names, addresses, and telephone numbers).

Acknowledgments

Grateful appreciation is expressed to each program participant who gave his or her time and energy to prepare and present this useful information. Appreciation is also expressed to the planning committee members and others who worked to plan and implement this workshop. Many thanks to Mrs. Donna Bland for her patience and work in the typing of these proceedings.

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Flavor Evaluation and Off-Flavor Metabolite Depuration from Channel Catfish (*Ictalurus punctatus)*

Christopher P. Dionigi

Channel catfish (*Ictalurus punctatus*) exposed to the earthy/musty microbial metabolites 2-methylisoborneol(1-R-exo-1,2,7,7-tetramethyl-bicyclo-[2,2,1]-heptan-2-ol) (MIB) and geosmin (1α,10β-dimethyl-9α-decalol) can become "off-flavor" and therefore unacceptable for harvest and sale. However, following a cessation of exposure, fish regain flavor quality. To determine the period required for fish to regain flavor, fish were captured from commercial ponds, they were transferred into 2,000-liter fiberglass tanks, and the time course of decline in off-flavor metabolite concentration was determined. Smaller fish were leaner than larger fish and regained flavor quality more rapidly than larger fish, suggesting that production of leaner fish may augment efforts to reduce off-flavors. Analysis of the upper confidence limits indicated that the time required for 80%, 90%, 95%, and 99% of the fish in each size class to reach acceptance thresholds ranging from 0.1 to 1.0 parts per billion (ppb) ranged from about 140 to more than 500 hours. In addition, populations of fish may contain both acceptable and off-flavor individuals. Optimal sampling strategies to determine the marketability of fish populations must take into account these sources of variation.

Trimming Reduction Technology: A QA Maintenance Challenge

Guy Ewing

The machines used today in the farm-raised catfish industry to produce boneless fillets were originally designed to process other species. The Baader (BA) model 166 heading and eviscerating machine, for example, was created to process codfish, whiting, and other similar groundfish species aboard ships at sea.

The fish clamping system used on this machine was designed to hold fish in a semi-live state aboard a rolling vessel. This fish clamping system, therefore, was the logical choice to handle stunned, but alive, pre-rigor catfish. Baader (Fort Myers, Florida) made several modifications to the original model 166 to adapt it for catfish and create the model 166C.

The Baader catfish filleting machine model 184C was also originally designed for North Atlantic codfish. Major modifications were developed for this machine to adapt it for catfish, especially in the rib scraping section to accommodate the rib cage and nugget structure.

However, neither the model 166 heading and gutting machine nor the model 184 filleting machine was completely transformed into a catfish-processing machine. The anatomy of a catfish is quite different from that of a codfish. This combination of the unique anatomy of the catfish, and using machinery originally designed for codfish, is the origin of most of the fillet defects that require manual trimming.

On average, untrimmed and skinned fillets emerging from the BA 184/51 filleting/skinning machine contain 9% trim material. The remaining marketable components are shank fillets and nuggets.

If we examine the composition of the trim material, we find four major components – tail fins, viscera remnants, dorsal bone plate, and pelvic fins and the associated pelvic bone. While other defects can and do occur, these are the primary items caused by the anatomy of the catfish and the design of the machinery.

Origins of Trimming Defects

What causes defects in catfish fillets? As previously noted, there are two general causes: the unique anatomy of catfish and incomplete "*catfishization*" of the processing machinery.

An illustration is the defect of tail fin pieces on the fillets. Since fish are transported tail first in the filleting machine, the shape and characteristics of the tail fin is important to guiding the fish. However, remember that the BA 184 filleting machine was originally designed for codfish. Codfish have a rigid and full triangular-shaped tail fin. Catfish, on the other hand, have a deep v-shaped tail fin that lacks the rigidity to guide the fish. Consequently, the catfish tail fins are pushed outside the guiding rails and are cut off by the filleting blades. This condition is aggravated by incorrect centering adjustments of the guides and tools.

A further trimming function arising from the inherent nature of the animal is the pelvic fin and pelvic bone. Catfish have pelvic bones with attached pelvic fins. The eviscerating machine splits open the belly of the fish, which places a pelvic fin and bone on each side of the fish. When the fish is filleted, a pelvic fin and pelvic bone remain on each nugget and must be manually trimmed away.

The final significant trim function is cutting or scraping away the viscera remnants on the fillet and nugget. How do catfish remnants (kidney pieces, roe skeins, and intestinal cords) end up on the fillets? The answer is simple: incomplete eviscerating of the fish before filleting.

Several other defects also occur in catfish fillets that require manual trimming: rib bones, pieces of the main bone, and other fins. However, most of these defects are a result of improper adjustment or lack of proper maintenance of the machinery.

Another trimming function caused by the unique anatomical characteristics of the catfish is trimming of dorsal fin bone plates. Much to our dismay, catfish have a triangular bone plate just below the dorsal spike. Codfish have no such structure. When the back filleting blades cut longitudinally along each side of the dorsal ray, they cut through each triangular bone plate and leave a piece of the bone plate in each fillet. These bone plate pieces must be trimmed from every fillet.

Baader Catfish Trimming Reduction Concept

How does the Baader trimming reduction system reduce trimming? Trimming reduction is accomplished by a combination of new machinery and modification of existing machinery to perform many trimming functions automatically. This system consists of a heading/eviscerating/tail-cutting machine, a number of attachments for the BA 184C filleting machine, and an ergonomic design of the trim and inspection stations. Removal of the pelvic fin and bone from the nugget is accomplished automatically in the new BA 194 filleting/trimming machine. The pelvic fin/bone is scraped from the nugget by a self-cleaning tool.

Reducing viscera trimming is directly addressed in the new BA 148 heading and eviscerating machine. This machine eliminates a major amount of viscera from the fish, which significantly reduces the labor required to trim this defect.

Fillet handling is a major component of the time required to trim catfish fillets. Fillet handling is reduced in the trimming reduction program by an efficient trim/inspection table. The approach with this system is to minimize handling of fillets that require no trimming. Picture, if you will, a system where fillets from the BA 194 are inspected and those that require no trimming are passed directly to the skinning machine, while those that need some manual trimming are diverted to trimmers. Significant trimming labor reduction will be obtained through efficient and ergonomic trimming/inspection stations.

First, the tail-fin-trimming function is reduced by making a tail fin cut in the new BA 148 heading and gutting machine. The cut squares off the tail fin and virtually eliminates pieces of tail fins on the fillets.

The next trimming reduction function is the dorsal spike bone plate. The new Baader 194 filleting/trimming machine makes a dorsal fin trimming cut. This cut involves an incision on each side of the dorsal bone plate that separates the dorsal plate from the fillet meat.

Included also in the new BA 194 is a nugget separation cut. This is accomplished by a modification to the rib scraper blades and makes an incision along the nugget line just to the skin. Then, when the fillet is skinned, the nugget separates from the shank fillet.

Recommendations to Manage a Trimming Reduction Program

(1) Create a position in your company of “Head Baader Mechanic” whose responsibilities include overseeing Baader machine maintenance and training your in-plant Baader mechanics.

(2) Pay a higher wage to Baader machine mechanics. Elevate the status of this position. This recognizes that yield throughput and reduced trimming have paybacks.

(3) Certify your in-plant Baader mechanics through an official training program at Baader.

(4) Assemble a trimming reduction team to include key personnel from maintenance, production, and quality control. The responsibility of this team is to assure that the trimming reduction technology is utilized to its maximum.

(5) Budget and track Baader machine maintenance separately from other plant equipment. Expenditures for Baader machine maintenance should focus on high yields, low down time, and reduced trimming.

(6) Monitor machine performance. A system should be installed to monitor the throughput and yield of each processing line. Line performance should be evaluated in terms of recovery from headed and eviscerated fish, shank to nugget ratio, and throughput.

(7) Implement a preventative maintenance program. This program should include daily, weekly, and monthly checklists of maintenance.

(8) Train production personnel in the basics of how the machinery operates. They should understand its limitations and capabilities.

Influence of Preharvest and Postharvest Handling on Quality of Channel Catfish Fillets

Juan L. Silva, Atilano Nuñez, J. Eduardo Figueroa-Garcia, Roberto S. Chamul, and Taejo Kim

The channel catfish industry started as a cottage industry about 30 years ago but has grown into the largest aquaculture industry in the United States today. More than 590 million pounds of catfish were processed in 2000. A large percentage of thse catfish were marketed as fillets. Catfish processing used to be done manually, and thus it could take hours to produce a fillet. Today, with the advent of technology, industry growth, and labor shortages, a fish could be processed and its parts ready for distribution in 20 to 30 minutes. With about 3 million pounds a day to harvest and process, the industry has become very efficient. Filleting lines now process more than 40 fish per minute each, leaving little room for error.

These factors have brought about changes in the growing, harvesting, handling, and processing of the fish. These factors – along with others such as environmental conditions, feeding, stocking rate, management, and genetics – are known to affect the quality and safety of the final product.

During harvest and live transportation, such factors as single vs. multiple harvest, harvest season, holding time in the net, transportation (hauling) time, and oxygen are known to affect final product quality. Once in the plant, receiving, stunning, season, temperature of the fish, chilling, and time to icing/refrigeration/freezing affect the final product. This report will address some preharvest and postharvest handling methods that affect the quality of the final product, in this case fillets.

One study addressed the issue of handling stress before stunning on the quality of fillets. In this study, catfish were anesthetized (AN) with Finiquel™ (tricaine methanosulfonate, 50 mg/L), stressed (ST) by hauling in a truck for 30 minutes, nonstressed (NS), or cooled (CH) in holding vats by dropping water temperature from 70°F to 35°F in 30 minutes with ice. The fish were then killed rapidly, and rigor/blood measurements were done. Other fish from each treatment were filleted by hand; these fillets were placed in Styrofoam trays with a PVDC overwrap and stored at 36°F for up to 13 days.

Onset of rigor (Table 1) was fastest for ST fish (less than 4 hours), followed by NS fish (about 5 hours), and then the others (about 17 hours). One other treatment (ST+CH), rapid cooling of stressed fish after harvest (from 73°F water to 32°F water in 45 minutes), resulted in the fastest onset of rigor, less than 1.5 hours. These results related to plasma cortisol levels, with ST being the highest followed by NS. AN and CH fish had lower plasma cortisol levels.

The K value, an index of fish freshness, was twice as high in ST fillets and lowest in NS and CH fillets, throughout storage (Table 2). This was the result of larger hypoxanthine levels in ST fillets. At the end of storage, muscle pH was lowest for ST fillets.

Although none of the fillets was spoiled after 13 days, psychrotrophic counts (PPC) in ST and AN fillets were 1.5 to 2.3 log CFU/g higher. Despite having the second highest PPC initially, CH fillets had the lowest PPC after 13 days (Table 3). Both CH and AN fillets had the highest muscle pH at the end of storage.

Hunter ‘L’ values (brightness) of all fillets increased with storage, and was highest for NS and AN fillets. This shows that these fillets were less translucent and chalkier than fillets from ST and CH fish at the end of storage. Hue values (color) increased for all treatments except in AN fillets, which also showed the highest saturation index or chroma values (Table 4). This may be the result of changes in the state of hemoglobin and myoglobin, the two major pigments in the fish muscle.

Initial shear force (firmness) values for most treatments were about 50 N; shear force values for ST fillets were lower (43.5 N). After 13 days of storage at 36°F, AN and CH fillets exhibited a firmer meat than ST and NS fillets (Table 5). Water-holding capacity (WHC) was also highest in ST and NS fillets at the end of storage. Higher WHC indicates less ability of the muscle protein to hold water and thus may indicate more protein denaturation.

A second study addressed the effect of holding round and gutted fish in ice at refrigeration temperature for up to 30 hours before filleting. Preliminary results showed that harvest season affected muscle pH and moisture content of fillets, resulting in an effect on muscle color and firmness. Fillets from fish harvested in the cooler months had lower pH and moisture, but they had higher shear force (firmness) and chroma values and lower hue values than those from fish harvested in warmer months. There were some changes with holding time, but the data showed that holding round and gutted fish for up to 26 hours on ice may result in lower initial plate counts and a firm texture fillet.

Results obtained show that holding fish after harvesting and before processing (holding vats) for a few hours may result in a better texture and longer shelf-life product. Chilling whole fish (nonstressed) before processing may also have an effect similar to or better than for nonstressed fish. However, harvest season and other factors may influence the outcome.

Table 1. Onset of rigor (Rigor Index)[1] on whole channel catfish as affected by preprocessing treatment.

Hours after death	Treatments[2] ST+CH	ST	NS	AN	CH
0	0	0	0	0	0
1	100	20	5	<5	<5
2	100	50	10	5	5
4	100	100	15	5	5
8	100	100	40	20	15
12	100	100	80	30	40
16	–	100	100	50	65
18	–	100	100	100	100

[1]Rigor index: 100% = full rigor; 0% = pre-rigor.
[2]ST = Stressed after harvest (in transit for 2 hours) before death. NS = Held for 6 hours in vats without stress before death. AN = Anesthetized while in vats and before death. CH = Hold in vat water chilled to 35°F in 30 minutes. ST + CH = Stressed and immediately chilled.

Table 2. Effect of preslaughter treatment and storage time at 36°F on K value (%) of channel catfish fillets.[1]

Days stored at 36°F	Treatments[2] ST	NS	AN	CH
1	15.6 Ae	10.7 Ce	13.1 Be	7.5 De
4	28.5 Ad	15.8 Cd	24.5 Bd	12.5 Dd
7	46.7 Ac	30.9 Cc	44.2 Bc	24.9 Dc
10	53.6 Ab	44.9 Bb	53.2 Ab	37.2 Ab
13	61.8 Aa	54.1 Ca	60.2 Ba	51.6 Da

[1]abcde – Means within column not followed by the same letter differ ($P \leq 0.05$) as determined by Fisher's Protected LSD. ABCD – Means within row not followed by the same letter differ ($P \leq 0.05$) as determined by Fisher's Protected LSD.
[2]ST = Stressed fish; NS = Nonstressed fish; AN = Anesthetized fish; CH = Chilled fish.

Table 3. Effect of preslaughter treatment and storage time at 36°F on psychrotrophic plate count (log CFU/g) values of channel catfish fillets.[1]

Days stored at 36°F	Treatments[2] ST	NS	AN	CH
1	1.2 Cd	1.1 Cd	2.2 Ae	1.7 Bc
4	1.4 Cc	1.4 Cd	2.8 Ad	2.0 Bc
7	2.3 Cbc	3.1 Bc	4.5 Ac	3.4 Bb
10	2.7 Cb	3.9 Bb	5.4 Ab	3.8 Bab
13	6.1 Aa	4.6 Ba	6.1 Aa	3.8 Cab

[1]abcde – Means within column not followed by the same letter differ ($P \leq 0.05$) as determined by Fisher's Protected LSD. ABCD – Means within row not followed by the same letter differ ($P \leq 0.05$) as determined by Fisher's Protected LSD.
[2]ST = Stressed fish; NS = Nonstressed fish; AN = Anesthetized fish; CH = Chilled fish.

Table 4. Effect of preslaughter treatment and storage time at 36°F on Hunter "L" values of channel catfish fillets.[1]

Days stored at 36°F	Treatments[2] ST	NS	AN	CH
1	47.9 Aab	48.4 Ab	48.6 Ab	43.4 Bc
4	45.4 Cbc	53.1 Aa	50.5 Abab	49.1 Bb
7	45.9 Cbc	52.4 Aa	49.3 Bb	54.2 Aa
10	49.1 Bab	53.10 Aa	48.4 Bb	50.78 Abb
13	49.4 Ba	53.1 Aa	52.4 Ab	49.1 Bb

[1]abcde – Means within column not followed by the same letter differ ($P \leq 0.05$) as determined by Fisher's Protected LSD. ABCD – Means within row not followed by the same letter differ ($P \leq 0.05$) as determined by Fisher's Protected LSD.
[2]ST = Stressed fish; NS = Nonstressed fish; AN = Anesthetized fish; CH = Chilled fish.

Table 5. Effect of preslaughter treatment and storage time at 36°F on shear (Newton's) values of channel catfish fillets.[1]

Days stored at 36°F	Treatments[2] ST	NS	AN	CH
1	43.46 Ba	50.00 Aa	49.27 Aa	52.31 Aa
4	47.67 Aa	32.01 Ba	33.76 Bb	52.58 Aa
7	29.76 Bb	44.29 Aa	32.37 Bb	36.03 Ab
10	23.64 Cb	25.04 Bcb	30.08 Ab	32.95 Ab
13	25.68 Bcb	25.68 Bb	30.29 Ab	32.91 Ab

[1]abcde – Means within column not followed by the same letter differ ($P \leq 0.05$) as determined by Fisher's Protected LSD. ABCD – Means within row not followed by the same letter differ ($P \leq 0.05$) as determined by Fisher's Protected LSD.
[2]ST = Stressed fish; NS = Nonstressed fish; AN = Anesthetized fish; CH = Chilled fish.

Evaluation of Catfish Strains – Objective and Sensory Indices

Shin Young Park, Brian Bosworth, and Juan L. Silva

Quality attributes of 'USDA-103,' 'Norris,' and 'Channel x Blue' catfish were studied on raw, frozen-thawed, and cooked fillets. The aim was not only to see if there were differences among them but also to see what the consumer prefers and how consumer perceptions relate to objective, quantitative quality parameters.

Results from measurements on raw fillets showed that fillets from 'Norris' were brightest (higher Hunter 'L' value) and had the highest hue and color saturation (Table 1). 'Channel x Blue' fillets had the highest surface pH and shear force and the lowest compression force (firmer muscle) values (Table 2). Hunter color values for all products were higher than those reported in the literature, possibly due to harvest season, handling, and holding time before analysis (Table 3). Warner-Bratzler shear force, used commonly to measure muscle food firmness, cannot be used in catfish since it yields a large variation possibly due to their wide differences in thickness. Large variation in the measurements may be in part due to the lack of homogeneity/uniformity of the fillets and to their size/weight differences ('Norris' were the smallest and 'USDA-103' the largest). Fillet yields (including the nugget) were highest for 'Channel x Blue' strain, since they had the smallest head-to-body ratio.

As in the first experiment, frozen-thawed fillets from 'Norris' had higher Hunter 'L' (brighter) values and hue than other strains, but only on baked products (Table 4). The range in color values was similar to that reported in previous literature. 'Norris' fillets also had lower muscle and surface pH, and higher shear and compression forces (firmer meat), when baked. 'Norris' had the lowest fillet yields. Their small-sized fillets may have contributed to their lower pH and higher shear force values (firmness). As in the first experiment, variation in the data may have contributed in part to differences in size of fillets and in their lack of uniformity. Some sensory attributes seem to relate to instrumental-generated data (color, firmness), but additional training of panelists and better uniformity of products are needed to develop better correlation between sensory and quantitative data.

A taste panel rated 'Channel x Blue' baked fillets lower in overall acceptability (Table 5). This may be due to its fillets being slightly darker and less firm than fillets from 'Norris' and 'USDA-103.' Panelists seem to prefer "white" muscle catfish fillets with a firm texture. However, more work is needed to develop instrumental methods to assess product acceptance.

In addition, it is necessary to use a large variability of fish fillets from "good" to "bad" ones to be able to discern differences in parameters and correlate instrumental and sensory parameters. It looks as if quality parameters do not differ between these strains of fish.

(This research was funded in part by a grant from the "William H. White" Fund.)

Table 1. Hunter color[1] 'L,' 'a,' 'b,' Hue[2], and SI[3] values of raw fillets from three strains of catfish based on 120 observations in the data set.

Strain	'L'	'a'	'b'	Hue	SI
USDA-103	73.92 ab[4]	8.35 b	22.01 b	68.51 b	23.69 b
Norris	75.31 a	8.81 ab	25.74 a	70.65 a	27.31 a
Channel x Blue	72.06 b	9.25 a	22.75 b	67.16 b	24.70 b
CV (%)	9.02	20.94	19.63	8.47	16.97
LSD	1.68	0.46	1.17	1.47	1.08

[1]Hunter color values; L = lightness (0 = dark/opaque, 100 = light); a = redness/greenness (+ = red, - = green); b = yellowness/blueness (+ = yellow, - = blue)
[2]Hue angle = arctan (b/a).
[3]SI (Saturation Index) or Chromaticity = sqrt ($a^2 + b^2$).
[4]abc – Means in a column with the same letter, indicate no significant difference by LSD at the 5% level of probability.

Table 2. Surface pH, muscle pH, and shear and compression force values of raw fillets from three strains of catfish based on 120 observations in the data set.

Strain	Surface pH	Muscle pH	Shear Force	Compression Force
			N	*kN*
USDA-103	6.39 b[1]	6.39 a	1535 b	151 a
Norris	6.42 b	6.33 c	1488 b	132 b
Channel x Blue	6.52 a	6.36 b	1670 a	122 c
CV (%)	2.05	1.84	14.5	24.8
LSD (0.05)	0.03	0.02	57.5	8.5

[1]abc – Means in a column with the same letter indicate no significant difference by LSD at the 5% level of probability.

Table 3. Changes in color[1], color intensity[2] (CI), light reflectiveness[3] (LR), firmness[4] (FR), and odor intensity[5] (OI) values of frozen-thawed raw fillets from three strains of catfish (based on 300 observations in the data set).

Strain	Color	CI	LR	FR	OI
USDA-103	8.69 a[6]	8.03 ab	7.77 ab	5.85 ab	6.90 a
Norris	9.77 a	7.30 b	6.98 b	5.97 a	6.44 a
Channel x Blue	7.19 b	8.44 a	8.50 a	5.05 b	6.13 a
CV (%)	27.05	36.04	35.05	45.84	47.30
LSD (0.05)	1.27	0.91	1.04	0.90	1.05

[1]Color ranged from red (0) to white (15) with a middle of pink on 15-cm line.
[2]CI ranged from light hue (0) to very intense/deep hue (15) on 15-cm line.
[3]LR ranged from opaque (0) to shiny (15) on 15-cm line.
[4]FR ranged from soft/mushy (0) to tough (15) with a middle of firm on 15-cm line.
[5]OI ranged from none (0) to strong mushroomy (15).
[6]abc – Means in a column with the same letter indicate no significant difference by LSD at the 5% level of probability.

Table 4. Changes in color[1], light reflectiveness[2] (LR), flakiness[3], firmness[4], and taste[5] values of cooked fillets from three strains of catfish based on 300 observations in the data set.

Strain	Color	LR	Flakiness	Firmness	Taste
USDA-103	8.37 a[6]	7.89 a	8.88 a	7.13 a	7.46 a
Norris	9.22 a	7.15 a	8.70 a	6.75 a	6.68 a
Channel x Blue	8.08 a	7.54 a	8.19 a	6.66 a	6.79 a
CV (%)	29.91	32.64	36.95	36.03	59.30
LSD (0.05)	1.22	0.97	0.83	0.88	1.42

[1]Color ranged from dark brown (0) to white (15) on 15-cm line.
[2]LR ranged from opaque (0) to shiny (15) on 15-cm line.
[3]Flakiness ranged from not flaky (0) to very flaky (15) on 15-cm line scale.
[4]Firmness ranged from soft/mushy (0) to tough (15) with a middle of firm on 15-cm line.
[5]Taste ranged from none/bland (0) to sweet/nutty (15) on 15-cm line scale.
[6]abc – Means in a column with the same letter indicate no significant difference by LSD at the 5% level of probability.

Table 5. Overall acceptability[1] (OA) values of frozen-thawed and cooked fillets from three strains of catfish based on 600 observations in the data set.

Strain	Frozen-thawed fillet	Cooked fillet
USDA-103	4.24 a[2]	3.90 b
Norris	4.15 a	3.95 b
Channel x Blue	4.44 a	4.22 a
CV (%)	37.41	33.98
LSD (0.05)	3.39	0.26

[1]Overall scores range from 1 = like extremely to 9 = dislike extremely.
[2]abc – Means in a column with the same letter indicate no significant difference by LSD at the 5% level of probability.

Future of Ozonation

Gladden Brooks

Ozone is an elemental form of oxygen occurring naturally in the Earth's atmosphere. It is also formed by the action of electrical discharges of oxygen, so it is often created by thunder and lightning. After a thunderstorm, the air seems to smell like fresh-mown hay, due to the small amounts of ozone generated by the storm. Ozone is an unstable molecule made of three oxygen atoms (O^3) that readily decomposes back to a harmless, environmentally safe material, namely oxygen. Because it is unstable, it cannot be purchased as a compressed gas but must be produced on site and used shortly after generation. Ozone is produced commercially in ozone generators, which involve sending an electrical discharge through a specially built condenser containing oxygen.

Ozone has certain characteristics that make it attractive as a sanitizer for food processing, and it is probably safer than other sanitizer systems. Ozone is a powerful oxidizer, with 150% of the oxidizing potential of chlorine. It can kill a variety of viruses, bacteria, and other toxins in the water. It also oxidizes phenolics, pesticides, detergents, chemical wastes, and smelly compounds more effectively than chlorine, yet without its harmful residues.

Today, more than 200 municipalities around the world purify their water supplies with ozone, including Los Angeles, Paris, Montreal, Moscow, Singapore, Brussels, and Amsterdam. Tests have shown it is effective in eliminating off-color problems, such as the ones that exist in the Pascagoula and Greenville water supplies, by destroying organics such as lignin. Ozone is also being used to purify public swimming pools, disinfect municipal wastewater, and clean up lakes and streams that have become polluted by sewage and other pollutants.

The bottled water, soft drink, and brewery industries are moving toward the use of ozonation for disinfection. Breweries use ozone to remove any residual bad taste from water used in beer production. The pharmaceutical industry uses ozone as a disinfectant. Ozone can be used for odor control. Applications include smoke odor removal after building fires and odor removal in medical doctors' waiting and examining rooms, hospitals, and nursing and personal care homes.

Gaseous ozone is being used to increase shelf life, and ozone dissolved in water is used to inhibit the growth of molds and bacteria of fruits, vegetables, and other agricultural products. Studies at Michigan State University indicate a degradation of pesticide residues by using ozone on fresh produce.

Many fishing trawlers in Japan and Europe use ozonated ice on-board for shelf-life extension. Studies of fresh Alaska salmon found that refrigerated shelf life can be extended by 33% to 50%. I have observed standard plate counts on heavily ozonated catfish fillets to be less than 10 microorganisms per gram.

In 1957, Congress amended the Food, Drug and Cosmetic Act, requiring pre-market approval for food additives that were not "prior sanctioned" or were not on the FDA's list of products that were considered "generally regarded as safe" (GRAS). The list was not inclusive and did not include ozone. Up until 1997, only the use of gaseous ozone in meat-aging coolers (1975) and for treatment of bottled water for drinking (1995), when used in accordance with GMPs, was recognized as GRAS. In 1997, with Electrical Power Research Institute (EPRI) assistance, ozone was approved as safe (GRAS) for food processing, opening up a new realm of sanitizing and disinfectant possibilities. There are several potential applications of ozone in catfish processing:

(1) Slime removal and cleaning of holding vats;
(2) Ozonation of vat water to reduce bacteria;
(3) Treating of chiller makeup water;
(4) Treating whole fish and fillet with ozonated spray wash before packing;
(5) Using ozonated water during cleanup operations; and
(6) Treating wastewater streams to reduce loadings to effluent systems.

One area of application, recycling of chiller water, has been implemented in several poultry processing facilities. This involves a system that filters process chiller water, treats the water with ozone (or in combination with other treatments), and then recycles the treated water back to the chiller. The objective is to effectively sanitize the water, dramatically reduce water consumption, and reduce energy consumption. Research efforts in the departments of Food Science and Technology and Poultry Science at Mississippi State University include developing statistically valid data on the relationship of different amounts of ozone on catfish and poultry quality parameters such as shelf life, micro counts, etc.; application of ozone-treated water used for equipment cleaning; and treatment of processing plant well water sources.

Ozone breaks down naturally, but it takes up to 20 minutes for a half-life reduction. It is important to provide sufficient time for ozone degradation or to accelerate the process, such as by passing the ozonated water through a UVC disinfection system.

There is limited commercial skill in the United States dealing with the use of ozone in foods. It is important that ozone installations be installed and operating specifications be developed to insure worker safety and the efficacy of the process. Improperly designed systems or operating procedures could endanger workers by release of excess ozone or result in a failure to the process and product damage because of inadequate generation or distribution of ozone.

Ozone can be toxic to humans who breathe a high concentration over a long period of time. OSHA has established exposure limitations for workers exposed to ozone.

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Cumulative Trauma Disorders of the Upper Extremity

Lesia L. Crumpton

The surge in world competition has forced manufacturers to improve quality, increase productivity, and reduce costs. Work-related injuries are resulting in rising medical and legal costs. Cumulative Trauma Disorders (CTDs) are among the fastest growing occupational illnesses in the United States. Following are significant facts on CTDs:

• More than half of the nation's workers are working in occupations with the potential for CTD illnesses and injuries (such as keyboard operators and factory workers).

• Reported cases of CTDs have jumped from 72,000 in 1987 to 332,000 in 1994.

• OSHA reports there are more than 300,000 new CTD cases each year, which may be underreported.

• There were almost twice as many CTDs reported in 1991 as all other occupational illnesses combined (223,600 versus 144,700).

• CTDs were still almost 60% of the occupational illnesses reported in 1993.

• Costs per CTD case are prohibitive (ranging up to almost $280,000).

• Additional costs of CTDs include possible OSHA fines, legal damages, and lost workdays.

CTDs in U.S. Industries

The manufacturing industry has the highest percentage of CTDs, followed by construction, public utilities, and retail trade.

Why the increase of CTDs? (1) Production standards must be met. (2) Work pace is faster than in the past. (3) U.S. industries have seen an increase in service and high-tech jobs, which tend to be more repetitive, prolonged, and labor intensive. (4) The U.S. has an aging workforce; as it ages, the body's resilience to chronic wear and tear is reduced. (5) Reductions in worker turnover, which are more likely to occur during periods of high unemployment, reduce workers' flexibility for choosing less physically demanding jobs. (6) Increased awareness by medical practitioners also contributes to the increase of CTDs.

Symptoms of CTDs increase over time. Symptoms may be intermittent and nonspecific to begin with. There is usually some type of sensation, followed by discomfort and pain. Medical visits lead to OSHA reports.

Definitions

Cumulative trauma disorder (CTD) is a term that describes numerous musculoskeletal disorders that affect bone, nerves, soft tissue, and the ability to perform work. *Cumulative* indicates that these injuries develop gradually over periods of weeks, months, or even years because of repeated stresses on a particular body part. The cumulative concept is based on the theory that each repetition of an activity produces some trauma or wear and tear on the tissues and joints of the body. The word *trauma* signifies bodily injury from mechanical stresses. In addition, the term *disorders* refers to physical ailments or abnormal conditions.

A CTD usually develops gradually because of repeated microtrauma. Because of the slow onset and often-innocuous character of the microtrauma, the condition is often ignored until the symptoms become chronic and permanent injury occurs. CTDs of the upper extremity may affect the neck, back, shoulders, fingers, wrist, and/or elbow.

CTDs may result from several following workplace factors: (1) force; (2) repetition; (3) posture; and (4) lack of rest. Force + Repetition + Posture + No rest = CTDs.

CTDs may be affected by several nonoccupational factors: (1) leisure activities; (2) previous injuries; (3) predisposing diseases, such as diabetes, arthritis, and thyroid problems; and (4) pregnancy.

CTDs in Different Body Parts

Neck. Physical ailments or abnormal conditions of the neck include tension neck syndrome and posture strain. Contributing factors of these problems are prolonged static, restricted posture, and prolonged lifting of the head. These problems can be prevented or controlled by implementing job enlargement and stretching exercises.

Back. Physical ailments or abnormal conditions of the back include degenerative disc disease, herniated disc, mechanical back syndrome, ligament sprain, and muscle strain. Contributing factors include prolonged static load on the upper torso musculature, awkward posture (extensive trunk flexion or extension), and constant lifting of objects from the floor. Practicing the proper method of lifting objects from the floor is one way a worker could prevent and control back problems.

Shoulders. Physical ailments or abnormal conditions of the shoulders include thoracic outlet syndrome and shoulder tendinitis. Contributing factors include prolonged flexed shoulders, repetitive shoulder abduction/flexion, frequent reaching above the shoulders, tasks that pull shoulders back and down, prolonged load on shoulders, and repetitive throwing of heavy load. There are several ways to prevent or control shoulder problems: (1) increase recovery time where force requirements are high; (2) reduce frequent reaching above shoulders; (3) reduce awkward shoulder postures by using fixtures, clamps, etc.; (4) Reduce loads on the shoulders.

Fingers. Physical ailments or abnormal conditions of the fingers include digital neuritis, trigger finger, and Dequervian's syndrome. Contributing factors include the use of vibration tools such as pneumatic hammers, saws, and power grinders; repetitive ulnar deviation in pushing controls; ulnar deviation and flexed wrist with exertion; and forceful gripping. Implementing job rotation and/or job enlargement and the use of protective materials to absorb some vibration effects are two ways to prevent and control these problems.

Wrist. Physical ailments or abnormal conditions of the wrist include tendinitis, carpal tunnel syndrome, and cubital tunnel syndrome. Contributing factors include repetitive forceful wrist extension/flexion, high-speed finger movement, palmar base pressure, ulnar deviation, and rapid wrist rotational movements. Implementation of wrist exercises and rest periods/microbreaks can help to prevent and control these problems.

Elbow/Forearm. Physical ailments or abnormal conditions of the elbow/forearm include medial and lateral epicondylitis and radial tunnel syndrome. Contributing factors include repetitive forearm pronation, extreme rotation of the forearm, and extreme flexion of the elbow. Prevention and control methods include minimizing the degree the forearm has to rotate, implementing rest periods, and replacing hand labor with power tools if appropriate.

Prevention and Control of CTDs

Ergonomics provides a scientific study of human work, resulting in an evaluation of the physical and mental capabilities and capacities of the human operator. This evaluation looks at the operator as he or she interacts with tools and equipment and the methods, tasks, and working environment. By designing the workplace to fit the operator's capabilities and capacities, work-related disorders are reduced. Companies should establish an ergonomics program to prevent CTDs. An effective CTD prevention program would also include engineering and administrative controls, training and education for employees, and a medical control program.

Engineering controls focus on the work environment and are achieved by redesigning tools, workstations, and jobs. Ergonomic engineers can position the work and worker to eliminate awkward postures. For example, steps could be taken to raise the work or lower the worker to reduce wrist flexion, or to lower the work or raise the worker to reduce wrist extension. Other examples of engineering controls include making workstations and seating adjustable to allow for changes in posture, angling or tilting the work towards the worker, locating tools and parts within easy reach, using fixtures and jigs to support work pieces, rounding surface edges to avoid sharp protrusions, keeping parts bins below elbow height, designing jobs to reduce hand force and repetitions, and reducing the force needed to turn knobs and valves.

Administrative controls change work procedures or methods. For example, decisions can be made to reduce task frequency (if compatible with production demands), rotate workers between different types of jobs, and allow workers to alternate hands, if possible. In addition, administrators could implement gradual break-in periods for new workers or for veteran workers during the early part of a shift. Management could also seek medical advice regarding the advisability of job placement exams, work-site exercise and stretching programs, and the use of wrist splints. Other administrative control measures include training workers in correct methods, educating workers about sources of problems, avoiding machine pacing, avoiding incentive pay scales, expanding the work content of the job, and training management and supervision about the problems and correct responses to affected workers.

Employee education could include training for workers in correct work methods. A company could also provide training on "How to use" new products, as well as on "Why they should be used." It is advisable to provide workers with literature or reminders on the operation of new equipment. Finally, workers should be educated about the occurrence of CTDs.

A **medical protocol** could include the use of job placement exams, wrist splints, and work-site exercise and stretching programs. A company might also consider establishing a return-to-work program, as well as an employee screening and monitoring program.

Influence of Process Flow on Microbial Profile of Channel Catfish Fillets

Siriluk Watchalotone, Juan L. Silva, T. C. Chen, and Chakrapong Handumrongkul

Channel catfish (*Ictalurus punctatus*) fillets harvested in the fall of 1995 were processed five different ways (Figure 1): (1) manual dehead-manual fillet/skin-chill-fillet (mDmF/SCF); (2) manual dehead-automatic fillet/unchill (mDaF/UC); (3) automatic dehead-automatic fillet/dehead-chill-fillet aDaF/DCF); (4) manual dehead-automatic fillet/eviscerate-chill-fillet (mDaF/ECF); and (4) automatic dehead-automatic fillet/trim-chill-pack (aDaF/TCP). They were examined for microbial profile, psychrotrophic (PPC), and total coliform (TCC) counts. Process flow type (how fish are processed into fillets) had no influence on either PPC (cold-loving bacteria) or TCC (indicators of cleanliness) (Table 1). Both PPC and TCC were slightly higher than commonly found, probably due to the additional handling of the fish. Ideally, one should not have over 100CFU/g TCC (TTC > 2 log CFU/g), and PPC should be as low as possible (10^3 - 10^4 CFU/g = 3-4 log CFU/g).

When looking at microbial profiles for each of the processes (Table 2), one could notice differences. Most of the Gram- bacteria found are known spoilers of fish and can grow/survive at cold temperatures. *Aeromonas* incidence (2.13%) was very low, despite being common bacteria in the live fish. This may indicate good sanitation and processing procedures (GMPs). Presence of *Pseudomonas* may indicate uncleanness or inadequate sanitation, whereas presence of *Acinetobacter* may indicate inadequate process (raw) water treatment. S*taphylococci* (6.38%) were predominant in products filleted before being skinned (typical automatic filleting lines). This organism can be isolated from infected workers and other sources. It may be desirable to clean the belts and skinner rolls, as well as fish skin, to minimize the presence of the organism.

This study showed that it is not only necessary to conduct total plate counts, but also to follow certain key microorganisms in your plant to discern any deviations or inadequacies that may lead to a shorter shelf-life or a possible food safety problem.

Table 1. Effect of process flow on total coliforms (TCC) and psychrotrophic (PPC) plate counts [log (CFU/g)] in channel catfish fillets.

Process flows[1]	TCC[2]	PPC[3]
DmF/SCF	2.65 (ns)[4]	4.88 (ns)
mDaF/UC	2.76	4.68
aDaf/DCF	2.55	4.54
mDaF/ECF	2.55	4.46
aDaF/TCP	2.66	4.49
LSD[5] (0.05)	0.28	0.36

[1]mDmF/SCF: Dehead(m) → eviscerate(m) → chill → fillet(m) → pack → ice
mDaF/UC: Dehead(m) → fillet(a) → skin(a) → trim(m) → pack → ice
aDaF/DCF: Dehead(a) → chill → fillet(a) → skin(a) → trim(m) → pack → ice
mDaF/ECF: Dehead(m) → eviscerate(m) → chill → fillet(a) → skin(a) → trim(m) → pack → ice
aDaF/TCP: Dehead(a) → fillet(a) → trim(m) → chill → pack → ice
m = Manual; a = Automatic.
[2]Total coliform count.
[3]Psychrotrophic plate count.
[4]No significant difference at $\alpha = 0.05$.
[5]Least Significant Difference.

Table 2. Number of bacterial isolates (% in parenthesis) from channel catfish as influenced by five different process flows.

Cultures	Process Flow[1]						
	A (%)	B (%)	C (%)	D (%)	E (%)	Total	Total (%)
Acinetobacter	2(8.70)	5(15.62)	2(7.14)	ND	6(26.09)	15	10.64
Flavobacterium	1(4.35)	4(12.50)	2(7.14)	3(8.57)	2(8.70)	12	8.51
Aeromonas	1(4.35)				2(8.70)	3	2.13
Pseudomonas	1(4.35)	4(12.50)	1(3.57)	2(5.71)	2(8.70)	10	7.09
Major Gram-, psychrotrophic bacteria	5(21.75)	13(40.62)	5(17.85)	5(14.28)	12(52.19)	40	28.37
Pasteurella	2(6.25)	1(3.57)		1(2.86)		4	2.84
Agrobacterium		1(3.12)				1	0.71
Plesiomonas				1(2.86)	1(4.35)	2	1.42
Oligella				1(2.86)	1(4.35)	2	1.42
Weeksella				1(2.86)		1	0.71
Alcaligenes					1(4.35)	1	0.71
ND[2] Gram-	14(60.87)	8(25.00)	7(25.00)	11(31.43)	6(26.09)	46	32.62
All Gram-	19	24	13	20	21	97	68.79
Staphylococcus		3(9.38)	4(14.28)	2(5.71)		9	6.38
Stomatococcus		1(3.12)	1(3.57)	6(17.14)	1(4.35)	9	6.38
Other Gram+ (cocci)	4(17.39)	4(12.5)	10(35.71)	7(20)	1(4.35)	26	18.44
All Gram+ (rod and cocci)	4	8	15	15	2	44	31.21
Number of colony isolates	23	32	28	35	23	141	100

[1]A = mDmF/SCF: Dehead (m) ⟶ eviscerate (m) ⟶ skin (m) ⟶ chill ⟶ fillet (m) ⟶ trim (m) ⟶ pack ⟶ ice
B = mDaF/UC: Dehead (m) ⟶ fillet (a) ⟶ skin (a) ⟶ trim (m) ⟶ pack ⟶ ice
C = aDaF/DCF: Dehead (a) ⟶ chill ⟶ fillet (a) ⟶ skin (a) ⟶ trim (m) ⟶ pack ⟶ ice
D = mDaF/ECF: Dehead (m) ⟶ eviscerate (m) ⟶ chill ⟶ fillet (a) ⟶ skin (a) ⟶ trim (m) ⟶ pack ⟶ ice
E = aDaF/TCP: Dehead (a) ⟶ fillet (a) ⟶ skin (a) ⟶ trim (m) ⟶ chill ⟶ pack ⟶ ice
m = Manual; a = Automatic.
[2]Not identified.

FISH

mDmF/SCF	mDa/UC	aDaF/DCF	mDaF/ECF	aDaF/TCP
Dehead m	Dehead m	Dehead a	Dehead m	Dehead a
Eviscerate m	Fillet a	Chill	Eviscerate m	Fillet a
Skin m	Skin a	Fillet a	Chill	Skin a
Chill	Trim m	Skin a	Fillet a	Trim m
Fillet m	Pack	Trim m	Skin a	Chill
Trim m	Ice	Pack	Trim m	Pack
Pack		Ice	Pack	Ice
Ice			Ice	

Figure 1. Process flow diagrams for catfish fillets (D = Dehead, E = Eviscerate, S = Skin, C = Chill, UC = Unchill, F = Fillet, T = Trim, P = Pack, m = Manual, a = Automatic).

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