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CATFISH PROCESSORS' WORKSHOP

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Proceedings

of the

1996 Catfish Processors' Workshop

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PREFACE

The purpose of the workshop was 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 "About the Speakers" for speakers' names, addresses, and phone 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. We also offer many thanks to Mrs. Donna Bland for her patience and work in the typing of these proceedings.

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Nutrition and Catfish Quality

Edwin H. Robinson

Historically, nutrition research has focused on developing feeds that promote rapid gain and efficient feed conversion. However, over the last several years considerable attention has been given to diet and product quality. Thus, the primary goal of nutrition research is to develop feeds and feeding practices that result in the most economical gain without adversely affecting product appearance, flavor, storage characteristics, and body composition.

A brief review of the growth process is essential to a discussion of diet and product quality. Growth can be defined in various ways, but a definition that appears to encompass the concept of growth best defines growth as a "correlated increase in the mass of the body in definite intervals of time in a way characteristic of the species." This definition implies that (1) there is variability in growth among individuals, (2) there is a characteristic growth rate of each species, (3) there is a characteristic adult size and development, and (4) the maximum size and development are fixed by heredity. Nutrition is the essential factor determining whether maximum genetic potential will be reached. An optimum nutritional regime, thus, is one that enables the organism to take full advantage of its heredity.

True growth results from an increase in structural tissues (muscle, bones, and organs) in contrast to weight gain that results from fat deposition. However, fattiness is inevitable in that it is an integral part of growing animals for meat. In fact, to achieve the rapid gain that is generally desired, high-energy, well-balanced rations are necessary, and while more efficient, they may result in increased fattiness. Factors other than diet and genetic line that affect fattiness include sex, size, age, and feeding practices. In general, female catfish are fatter than males, fat deposits increase with size and age, and animals that are fed under a restricted regime are less fat than if fed to satiation.

A typical commercial catfish feed is comprised primarily of defatted oilseed meals and grains or milling by-products with small quantities of animal protein, fat, phosphorus, vitamins, and trace minerals added for nutritional balance. These feeds generally contain 28-32% protein, 4-6% fat, 1-2% ash, 3-7% fiber, 30-40% carbohydrate, and 10% water. Catfish feeds are relatively simple and rather bland; thus, one would anticipate that feed would have minor if any adverse effects on product quality. This assumption appears to be true. Studies conducted on the effects of individual dietary ingredients on catfish flavor have not demonstrated any adverse effects with one exception. That is, high levels of fish oil (6%) impart a "fishy" taste to the flesh. The level of fish oil in a typical commercial catfish feed used for grow out generally does not exceed 2%. Thus, flavor is unaffected.

Dietary ingredients typically used in commercial catfish feeds generally do not affect appearance of processed catfish. The only report of an adverse effect on product appearance has been that high levels of corn gluten meal imparted a yellow coloration to catfish flesh. The high level of xanthophylls found in the meal apparently caused this. These yellow pigments are found in other feedstuffs, particularly corn, but at much lower levels than is found in corn gluten meal. High levels of corn can be used in catfish feeds without danger of discoloration of the flesh. It is recommended that the level of xanthophylls not exceed 11 ppm in the finished feed.

Opinions are mixed on the effect of diet on the storage characteristics of processed catfish. While an increase in tissue fat could potentially increase the likelihood of oxidative rancidity, there was no evidence of this in a recent study. The study was a collaborative effort among several universities in which the effects of diet on shelf life of processed catfish — and in particular the effect of increased fattiness on product quality — was evaluated. Based on the results from this study, there were no detrimental effects on fillet quality during frozen storage as fat levels increased. The effect of feeding high levels of vitamin E to limit oxidation was also evaluated. The results showed that tissue levels of vitamin E increased as the dietary concentration of the vitamin increased, but the increase in tissue vitamin E did not appear to enhance shelf life of processed catfish when the fish were properly frozen. In one experiment, in which oxidation was forced, vitamin E appeared to be beneficial. It appears that diet has little effect on the shelf life of processed catfish as long as the products are maintained under proper storage conditions.

A typical catfish fillet from a harvest-sized fish contains 75-80% moisture, 15-17% protein, 1% ash, and 5-6% fat. Thus, catfish contain a moderate level of fat, which is in part fixed by heredity but which may be

influenced by diet. The major dietary factor that affects fattiness in catfish is digestible energy to protein ratio (DE:P). For example, the DE:P ratio of catfish feeds should not exceed 9-10 kcal/g protein because fat tends to accumulate in body tissues as the ratio increases. Thus, as dietary protein is lowered, fat deposition may be increased unless dietary energy is also reduced. Fortunately, feeds commonly used in the catfish industry (28-32% protein) effect only relatively small changes in catfish fat content. For example, in one study, catfish fed diets containing either 32%, 28%, 24%, 20%, or 16% protein exhibited fillet fat levels of 4.6%, 5.2%, 5.7%, 7.8%, and 8.2%, respectively. There were no statistical differences in fillet fat content among fish fed diets containing 32%, 28%, or 26% protein, but fish fed diets containing 20% or 16% dietary protein had significantly higher fillet fat levels. Dressed yield (whole fish) was also reduced in fish fed diets containing 20% or 16% protein. However, other studies have indicated those increased levels of fillet fat result in a higher fillet yield.

Elevated body fat as the dietary DE:P ratio increases from the optimum range results in sort of a "Catch 22" for the practicing nutritionist. On the one hand, feed cost (which is the major variable operating cost involved in raising catfish) can be lowered substantially by reducing dietary protein. On the other hand, if protein is reduced too much, an increased fattiness is observed. The catch is that the catfish producer is paid on a live weight basis. Possible methods that might be used to lower body fat include (1) identifying methods to lower the DE:P ratio in low-protein diets without adversely affecting weight gain and feed conversion, (2) using finishing feeds designed to lower body fat, (3) using feed additives to reduce fat deposition, and (4) selecting for leaner catfish lines through genetic research.

In conclusion, it is obvious that maintaining product quality is of importance to the long-term viability of the catfish industry. While the effects of feed on product quality are generally positive, fattiness and associated consequences are problematic. If the goal is to reduce body fat by manipulating the diet, there is likely to be a significant increase in production costs. Unless the catfish producer is paid based on quality, there will be little incentive to participate. The concept would be difficult to apply, since there is no single simple measurement that can be made to fairly evaluate quality. In addition, who would judge product quality and who would pay the tab?

FishCheck™ for the Detection of Catfish Spoilage

Patrick M. Harewood

Traditional methods used to determine seafood quality include total plate count, trimethylamine determination, and sensory evaluation. Such methods are limited to the extent that they require specialized equipment and/or highly trained personnel, or are either too expensive or time consuming for the routine analysis of large numbers of fish.

FishCHECK™ is based on the principle that bacteria on the surface of the fish are able to metabolize a colorless indicator compound to produce a colored product. The colored product is then used as an indicator of the bacterial level on the fish.

This simple, visual, rapid and cost-effective test is used to determine the microbiological quality of fillets from various species of finfish during ice storage. This test also offers the advantage of time savings, requiring a person with little or no training for operation.

Materials and Methods

Catfish (*Ictalcurus spp.*) were obtained from a local wholesaler about 48 hours postharvest. The fillets were immediately placed in flaked ice, and transported to GEM Biomedical's Laboratory in Hamden, Connecticut. At specific time intervals, samples were subjected to analysis using GEM Biomedical's FishCHECK™ kit, microbiological analysis and sensory evaluation.

FishCHECK™ Test — Twenty-five-gram samples of catfish flesh were massaged by hand for 3 minutes with 25 milliliters of FishCHECK™ broth (1:1 ratio) using a 6x7-inch strainer bag. Five milliliters of filtrate from the strainer bag were then mixed with 1 milliliter of FishCHECK™ indicator reagent in a sterile test tube. The tube was allowed to stand at room temperature for 15 minutes and then shaken at 5-minute intervals. Three milliliters of Reagent A was added to stop the reaction, followed by 1 milliliter of Reagent B. The color that developed in the tube was determined using the PANTONE® Professional Color Chart.

Visual Determination of Color — The intensity of color developed in each FishCHECK™ assay was determined by comparing it with a series of color intensities (colorless to intense red) on a chart. Each color intensity on the chart is indicative of the state of decomposition of the fish analyzed, with colorless representing excellent (high) quality and intense red representing poor (low) quality. Intermediate color intensities represent good (high-medium) and fair (medium) quality.

The actual color values on the chart were rated numerically using the PANTONE® professional color system. Using this system, each color is given a numerical percentage value depending on its intensity.

Microbiological Determination — Samples of filtrate from the strainer bags were serially diluted with FishCHECK™ broth and subjected to microbiological analyses. Total aerobic plate counts (APC) were conducted on standard plate count agar incubated at 25°C for 48 hours before counting. *Pseudomonas putrefaciens* plate counts were conducted on peptone iron agar incubated at 25°C for 48 hours. APC and *P. putrefaciens* values were expressed as mean log CFU/g of 10 fillets per sampling day.

Trimethylamine Determination — Samples of fish tissue were subjected to trimethylamine (TMA) determination using a modification of the procedure of Dyer (1945).

Sensory Evaluation — At each period when samples of fish fillets were removed for microbiological and chemical analyses, a sample of fillet was placed in a plastic bag, vacuum packed, and stored at –20°C until the end of the study. The vacuum-packed fillets were then packed in dry ice and sent overnight to the National Sensory Branch of the National Marine Fisheries Service in Gloucester, Massachusetts, for analysis.

Samples were evaluated by a trained panelists using a "1" to "10" line scale, with "1" representing highest quality and "10" the lowest quality. These judges were trained to determine the quality factors of seafood and seafood products based on appearance, texture, and odor. Any quality factor(s) indicative of taint or decomposition, regardless of the amount of sample affected, resulted in the sample being failed (i.e., score >5). To fail a sample, the quality factors had to be both persistent and distinct.

Results and Discussion

Analyses of the relationships between indicators of catfish quality and the FishCHECK™ test showed a significant appearance in color was between 5 and 6 days of ice storage. At this stage, log total aerobic plate

count ranged from 7.2 to 7.4, whereas log *P. putrefaciens* count ranged from 6.0 to 6.2. Average sensory scores for 1- to 5-day-old fillets on ice storage ranged from 2.0 to 3.6; and for days 10-12 (the rejection period), ranged from 5.0 to 8.8.

Conclusions

FishCHECK™ is a simple, rapid, reliable method that can be used for the assessment of decomposition of catfish fillets during ice storage. The method shows good correlation with other existing methods used to determine fish quality. Other advantages include minimal sample preparation, ready-to-use sample reagents, room-temperature testing, room-temperature storage of reagents, and easy disposal of waste materials.

References

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How You Can Benefit from the Latest Plant Floor Information Technologies

Dave Church

Changes in plant floor information technologies provide a tremendous opportunity for improvements for monitoring, control, and planning of manufacturing operations. This is a brief overview of technology changes and approaches to take advantage of these changes.

Old manufacturing rules included approaches/beliefs such as bigger was better, design for long set-up and changeover times, lay out the factory by function, the supervisors' roles were to think and keep people busy, and the workers' roles were to keep busy and not to think *(1)*.

The impact of these approaches and beliefs was relative stagnation in productivity relative to quality, rate/yield, flexibility, and the workplace. The relative growth in productivity from 1960 to date was around 50% for the United States, as compared with more than 150% for Germany and almost 400% for Japan *(2)*. Productivity "is the ultimate weapon . . . more than any other factor, it will decide who wins and who winds up in the dustpan *(3)*." Imperatives for a more productive America include focusing on the effective use of technology, embracing product customization and production flexibility, and increasing employee breadth, responsibility, and involvement *(4)*.

Manufacturing information management involves the integration of the creation, retrieval, display, and modification of information for manufacturing, orientated toward using computer hardware and software in the process. The result is timely information and improved control. The results include improved quality, better resource management, increased flexibility, and reduced warranty costs, inventories, and cycle time.

Information management: How do you do it? Following are some of the necessary steps:

- Understand your business goals for improvements in areas such as quality, flow/rate, market share, customer satisfaction, and profitability.
- Determine where you currently stand related to areas such as process automation, material flow, and information technology.
- Recognize what you already have in place in terms of plant networks, control systems, and computer platforms.
- Involve active participation by cross-functional team members.
- Break down the execution into small steps and show paybacks for early actions.
- Anticipate the need for outside expertise (trusted technology partners) for both the planning and implementation phases.

Successful results can produce a direct impact on improved business performance. Approaches for success include planning top down, implementation bottom up, taking small steps to build a plant-wide solution, and having a self-directed workforce acting on shared information to deliver continuous improvement.

Several plant information technologies are available to improve productivity:

- **User interfaces —** These MMI's (man-machine interfaces) provide the link between the process and the people controlling the process. System usage and training time will directly correlate to ease of use. Graphical user interfaces provide the most intuitive link to the process, by encouraging use whereby the user recognizes the process and relates to the system better. These interfaces allow monitoring, diagnostic, and control capabilities. User-interface pointing devices include function/cursor keys, mouse, trackball, joystick, glide pad, and touch screen.

- **Integrated applications —** Integrates the users with the plant information systems and process equipment. This allows diverse information to be brought into a single system. Using graphic screens to display needed information is much more effective than alarm systems.

- **Distributed computing —** Allows the sharing of processing loads across several computers. In addition, it provides less expensive migration paths for expansion and limits exposure to hardware failures.

- **Networking —** Provides automatic data collection by computer to control device networking, connecting the plant information system and control devices.

• **Configuration —** Improved configuration technologies enable people to build better systems faster. The old programming approach required programming experience, and it was unstructured and least user friendly. The new software approach is window-based, requires no programming experience, and is structured and the most user friendly.

Monitoring and control programs to provide an integrated automated solution are called MES/SCADA (Manufacturing Execution Systems/Supervisory Control Automated Data Acquisition). The market consists of several players with no one dominant company in the MES/SCADA marketplace. Bluff City Electronics represents GE/FANUC Automation, which has $1.2 billion in revenues and is #1 worldwide in CNC (Computerized Numerical Control). There are several key questions for evaluating software partners:

- What components of the Windows 94 and NT software have been rewritten to run in the 32-bit mode, and what components are simply compiled from the old software?
- How many multitasking processes does the system support at once, and what impact will running these simultaneous processes have on the performance of the system?
- What software is used to integrate information with other applications?
- Has the software been tested thoroughly? What is the installed base for the newer version software?
- What is the company's migration plan to newer technologies and does the company have adequate resources to support that plan?

In summary, how can you benefit from the latest in plant floor information technologies? Following are several keys to success:

- Understand your applications and objectives.
- Address the needs of the entire team (all functions).
- Plan from the top, design from the bottom of the organization.
- Straighten out the information flow and needs before buying equipment.
- Focus on the effective use of information technologies.
- Start small and grow.
- Pick a partner and get on with it.

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(2) Barker, Joel A. 1992. Future Edge, New York, William Morrow & Co.

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Latest Regulatory Developments from the Food and Drug Administration

Leon Law

FDA-European Communities Export Health Certificate Program

The European Union (EU) required as of January 1, 1996, that all seafood in EU member states and those making product to ship to the EU have in place a Hazard Analysis and Critical Control Points (HACCP) program.

The European Communities (EC) is a group of European countries that have agreed to harmonize the commodity requirements to facilitate commerce among the members.

The EC has designated the FDA as a competent authority to sign EC forms, and the agency has implemented the FDA Export Health Certificate Program to meet the EC requirements and facilitate the shipment of fishery products to the EC.

An establishment that wants to participate in the EC Program is required to send a written request to the FDA district director that has several required components:

- Name and address of the establishment site that produces the fishery products intended for export to the EC.
- A list of the fishery products and packaging types processed at the establishment site intended for export to the EC.
- The name, mailing address, telephone, and FAX number of a designated contact person for the establishment.
- The name and affiliations of any other state and federal governmental agencies that inspect the establishment and/or analyze its products, and a statement that FDA will be provided access to these inspections and analytical records upon request.
- A signature acknowledging the United States Code of Federal Regulations, Title 18, which states it is a criminal offense to willfully make a false statement to United States officials in the performance of their duties or to alter or counterfeit official documents.
- A description of the steps taken by the establishment to assure that its products are in compliance with existing FDA laws and regulations (i.e., quality control and sanitation program, HACCP program).

HACCP

In December 1995, FDA issued seafood regulations based on the principles of HACCP. The FDA issued these regulations to ensure safer processing and importing of fish and fishery products.

HACCP is a common sense technique used to control food safety hazards. It is a preventive tool — not a reactive tool — used to protect the food supply against microbiological, chemical, and physical hazards. The plan is designed to minimize the risk of food-safety hazards; however, it is not a zero-risk system. A HACCP plan must identify food safety hazards (e.g., toxins, micro, chemical, pesticides, drug residues, physical hazards, decomposition, and parasites) that are reasonably likely to occur where a health hazard exists. HACCP has seven main seven principles:

(1) Conduct hazard analysis and identify preventive measures
(2) Identify critical control points
(3) Establish critical limits
(4) Monitor each critical control point
(5) Establish corrective action to be taken when a critical limit deviation occurs
(6) Establish verification procedures
(7) Establish a record-keeping system

All **processors** must conduct a hazard analysis to determine whether they have likely food safety hazards that they must control. If they identify no hazards, they do not need a HACCP plan for this time (assuming they are correct). However, they must reassess if a significant change occurs. If they do identify potential hazards, they must have and implement a HACCP plan.

President Clinton's March 1995 Reinvention Initiative

President Clinton's goal was to replace adversarial approaches with a partnership approach based on clear goals. He directed managers of regulatory agencies to hold grassroots regulatory partnership meetings with front-line regulators and the people affected by their work, and to create local partnership. The purpose of the grassroots meetings was to help shape the culture and direction of the FDA as it approached the year 2000. Among these meetings was a Seafood Grassroots

Partnership Meeting, which was divided into three groups. Each group compiled a series of vision statements.

Group 1 Vision Statements — HACCP:

- Enforce HACCP at all levels. Administer inspections at all levels from the harvester to retailer.
- An equal enforcement policy should exist for all processing facilities and importing countries.
- FDA should increase trust and decrease intimidation during inspections and other opportunities of interactions.
- All regulatory guidelines and action levels should be provided to industry.
- FDA should provide HACCP plans and/or guidance to industry.
- FDA should provide education and consultation expertise to processors to solve problems.
- FDA should provide prompt feedback from inspections and be accessible at all times.
- State and Federal FDA activities should be coordinated and consolidated.
- Product hazards should be considered in determining frequency of inspection.
- FDA should approve HACCP plans.

Group 2 Vision Statements — HACCP:

- FDA should help industry write a HACCP plan that everyone understands and includes effective methods to check the plan to make sure it is effective.
- FDA needs to accept USDC's HACCP program that is already in place.
- FDA should review each firm's HACCP plan in advance of its implementation.
- FDA should be more supportive and keep an open avenue of communication.
- FDA's main objective with HACCP should be to provide the consumers with safe and quality products.
- FDA should place responsibility on retailers as well as processors.

Group 3 Vision Statements — FDA Inspections/Level Playing Field:

- FDA's inspection efforts should promote uniformity to minimize differences between/among federal and state agencies/inspectors ("tell us who to listen to").
- If FDA is considering using third-party inspectors, then the third-party inspectors should be equally trained, certified, etc.
- FDA should develop regulations that are more concise and that will tell the precise methods to be used to do such things as pack, determine net drain weight, etc.
- FDA should negotiate with foreign governments to develop similar health requirements to ease logistical and financial burdens associated with importing and exporting seafood products.

Action Items Currently in Place

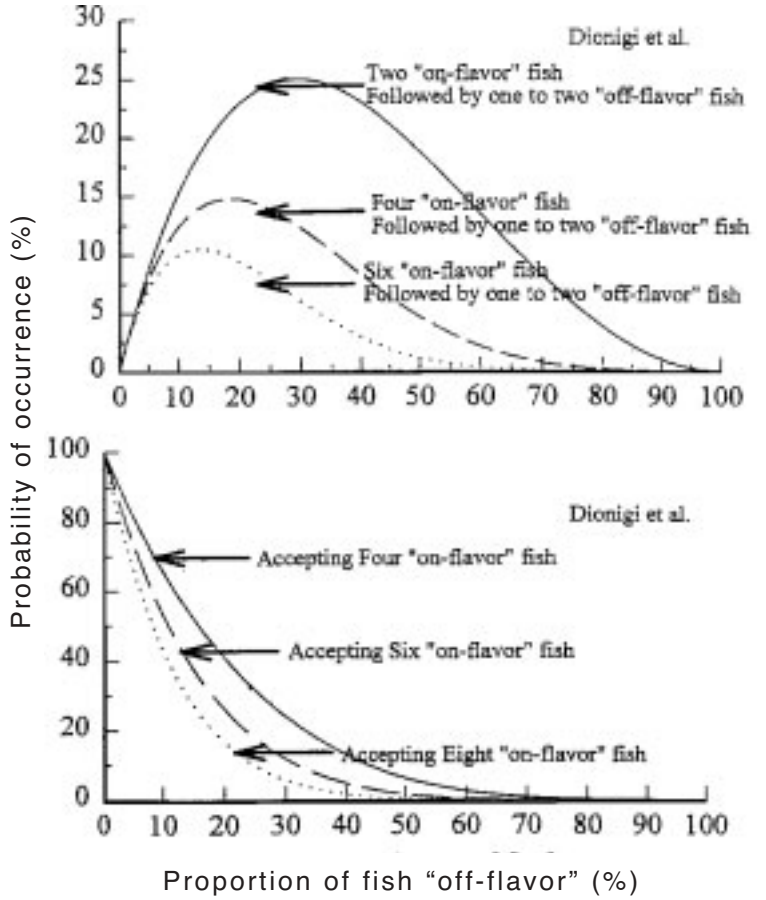
- Regional and district management will be available to meet with industry when requested to do so.
- In support of more open inspections, our investigative staff will communicate during inspections, pointing out and discussing observed problems as they are encountered rather than only at the conclusion of the inspection.
- Industry responses to FDA-483s (Inspection Observations) and to Warning Letters will not only be acknowledged, but we will advise the respondent whether the proposed corrective actions appear satisfactory, or more importantly, if they are unsatisfactory.
- We are pursuing with industry, state agencies, and the HACCP Seafood Alliance opportunities for joint training.
- We have conducted two Seafood HACCP Information Meetings in the Southeast Region to provide briefings on the final Seafood HACCP regulations.
- We have conducted three follow-up meetings to our June 10, 1996, Grassroots.

Variation in Channel Catfish (Ictalurus punctatus) **Flavor Quality and Its Quality Control Implications**

Christopher P. Dionigi, Karen L. Bett, Peter B. Johnsen,
Joseph H. McGilberry, David F. Millie, and Bryan T. Vinyard

Decisions to harvest or process populations of channel catfish (*Ictalurus punctatus* L.) are based upon flavor evaluations of a few fish. However, analysis of 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) concentrations in catfish filet tissues found populations containing acceptable (on-flavor) and unacceptable (off-flavor) individuals. In addition to these "mixed-flavor populations," analysis of 12,725 commercial processor flavor records found 120 instances of individual ponds yielding both off-flavor and on-flavor fish in 1 day or less. Factors that contribute to the occurrence of mixed-flavor populations have not been identified fully. However, uptake and depuration of lipophilic off-flavor metabolites by catfish are covariant with fat content, and the fat content of commercial fish populations ranged from 4.45% to 30.45%.

Additionally, the spatial distributions of algal populations were not uniform within catfish ponds. Commercial flavor assessment records collected in 1994 and 1995 indicated maxima in January and February and July and August in three parameters: the number of samples tested; proportion of earthy/muddy off-flavor samples; and proportion of non-earthy/muddy off-flavor samples. Panelist fatigue and other limitations of the sensory analysis of MIB and geosmin may increase observed variation within populations during these periods. Negative binomial simulations of sampling mixed-flavor populations indicated that shipment-rejections might occur stochastically. At current sampling frequencies, "objective" instrumental flavor analysis systems would not eliminate stochastic acceptance or rejection of mixed-flavor populations. However, instrumental MIB and geosmin analysis would contribute to consistent flavor-quality standards among processors and over time. Careful attention to proper sensory evaluation protocols, increased understanding of pond conditions associated with off-flavors, and optimization of sampling strategies offer near-term augmentations of current practice.



Negative binomial simulations of the probability of a stochastic rejection and acceptance of populations containing both on-fla-

Sensory Qualities of Catfish Fillets Treated with Selected Organic Acids

M. Farid A. Bal'a, Patti C. Coggins, and Douglas L. Marshall

Abstract

This study aimed to evaluate sensory qualities of raw and broiled catfish fillets treated with selected organic acids. Catfish fillets (*Ictalurus punctatus*) were dipped in 2% solution of chilled acetic, malic, and tartaric acid for 20 minutes and drained for 5 minutes. Control fillets were dipped similarly in 0.1% peptone water. Treated fillets were stored at 4°C for 8 days and analyzed. An eight-member untrained panel evaluated raw and broiled catfish fillets for surface color, freshness, texture, and overall acceptability. Sensory panelists scored raw and broiled catfish as lighter in color than untreated controls and found no objectionable flavors in fillets treated with either malic or tartaric acids. Organic acid treatments with malic or tartaric acid produced products with acceptable organoleptic properties.

Introduction

Efforts to enhance the microbial quality of catfish fillets have included (1) low-dose irradiation (Patterson, 1989), (2) modified atmosphere packaging with saturated carbon dioxide (Przybylski et al., 1989; Silva and White, 1994), (3) treatment with monoglycerides (Dorsa and Marshall, 1995), (4) inoculating foods with bacteriocin-producing competitor strains (Degnan et al., 1992), and (5) rinses with organic acids and/or their salts (Dorsa et al., 1993; El-Khateib et al., 1993; Palumbo and Williams, 1994).

Organic acid treatments exert a twofold impact on the microbiology of muscle food. Initially, a reduction in the number of microorganisms is observed, a characteristic often viewed as an enhancement of quality and safety (Prasai et al., 1991; Dickson and Anderson, 1992; Netten et al., 1995). An added benefit is continued antimicrobial action following acid treatment resulting in product shelf life extension (Kim et al., 1995a;b). The present study determined the impact of dip treating catfish fillets in 2% solutions of acetic, malic, or tartaric acid on the sensory qualities of raw and cooked catfish fillets over an eight-day time course.

Materials and Methods

Catfish preparation — Fresh channel catfish fillets were obtained from a local commercial processor and transported to the laboratory on ice. Sanitizing solutions (2%) of acetic (v/v, Fisher Scientific, Pittsburgh, Pennsylvania), malic (w/v, Sigma Chemical Co., St. Louis, Missouri), and tartaric acid (w/v, Sigma) were prepared in 0.1% sterile peptone water (PW). Whole fillets were aseptically placed in sanitized plastic steamer baskets (Rubbermaid Inc., Wooster, Ohio) and dipped into 2 liters of chilled (4°C) acid solutions for 10 minutes and drained for 5 minutes at 4°C. Baskets were gently rotated twice every minute to insure uniform surface exposure. Control samples were dipped in PW under the same conditions and drained for the same duration. Following treatment, samples were placed in Ziploc® bags (DowBrands L.P., Indianapolis, Indiana) and stored at 4°C.

Dip solution pick-up — Dip solution pick-up by samples was determined by weight difference. Samples were placed in steamer baskets and weighed before and after 10 minutes of dipping and 5 minutes of draining at 4°C.

Microbiological analysis — Plate count agar (PCA, Difco Laboratories, Detroit, Michigan) was prepared in 2-liter volumes following manufacturer recommendations. Prescribed weights were rehydrated in deionized water and poured into an Agarmatic sterilizer (New Brunswick Scientific, Tonawanda, New Jersey). Following sterilization, cooled PCA medium (55°C) was poured (15 milliliters per plate) using a Pourmatic (Model 320, New Brunswick Scientific). Prepared plates were allowed to stand at room temperature overnight to reduce surface condensation, then were bagged in cellophane sleeves, stored at 4°C, and used within 2 weeks of preparation.

Four fillets per treatment per analysis day were aseptically transferred to individual sterile stomacher bags (Spiral Systems, Bethesda, Maryland), diluted 1:1 (W/W) with PW and homogenized for 2 minutes in a stomacher (Tekmar Model 400, Cincinnati, Ohio). Total aerobic counts were determined by duplicate spiral platings (Model D, Spiral Systems) on PCA. Following 48 hours plate incubation at 35°C, counts were determined and expressed as mean $\log_{10}$ CFU/g.

Surface pH analysis — Fillet surface pH values were determined using a flat-ended pH electrode (Fisher). Surface pH was determined immediately after draining and subsequently after 2, 5, and 8 days of storage at 4°C. Surface pH values were expressed as means

of quadruplicate readings taken from four different locations of two fillets.

Sensory analysis — Catfish fillets were randomly removed from refrigerated storage, appropriately coded for each treatment, and placed on disposable paper plates. Using descriptive analysis with 15-centimeter scaling, an untrained eight-member panel evaluated raw and broiled catfish fillets. Unseasoned fillets were broiled in an oven for 15 minutes at 350°F on a rotating circular baking tray and evaluated for surface color, texture, and general acceptability. Uncooked treated and untreated fillets were evaluated for freshness and color.

Data analysis — Tukey test was used for the analysis of variance in microbial counts, surface pH, and sensory scores at a significance level of 0.05 to compare treatment means of samples of two replicate experiments using StatMost (DataMost Corporation, Salt Lake City, Utah).

Results and Discussion

Surface pH — Molarity measurements of the 2% acid dip solutions were 0.33M acetic, 0.15M malic, and 0.13M tartaric. Following a 10-minute dip and a 5-minute drain at 4°C, the resulting surface pH of the fillets strongly correlated (r=0.964) with the pKa of the treatment acid.

Fillets adsorbed 1.7 ± 0.3% of their weight from the acid dips, which explains the sustained low surface pH of acid-treated fillets during refrigerated storage (Figure 1). Surface pH of acid-treated fillets gradually increased with storage time (Figure 1); however, at all sampling times, acid-treated fillets had significantly lower ($P<0.05$) surface pH than PW-treated controls. By day 8, the lowest surface pH was on malic-acid-dipped fillets followed with tartaric and acetic acids (Figure 1).

Microbiological analysis — Initially following acid treatment, APC microbial counts were significantly lower ($P<0.05$) than on PW-rinsed control samples (Figure 2). The simple act of rinsing samples in PW without acid had no influence ($P>0.05$) on initial microbial counts or proliferation of aerobic microorganisms (Figure 2). Initial APC reductions were largest ($P<0.05$) for samples treated with malic and tartaric acid. Control samples were spoiled (foul odor) by day 8 with APC counts exceeding 10^6 CFU/g, while acid-treated samples were not malodorous.

Sensory analysis — Sensory panelists scored broiled fillets dipped in organic acids as lighter in color ($P<0.05$) than undipped controls. On day 0, texture scores of acid-dipped fillets were significantly ($P<0.05$) firmer than undipped controls (Figure 3); by day 5,

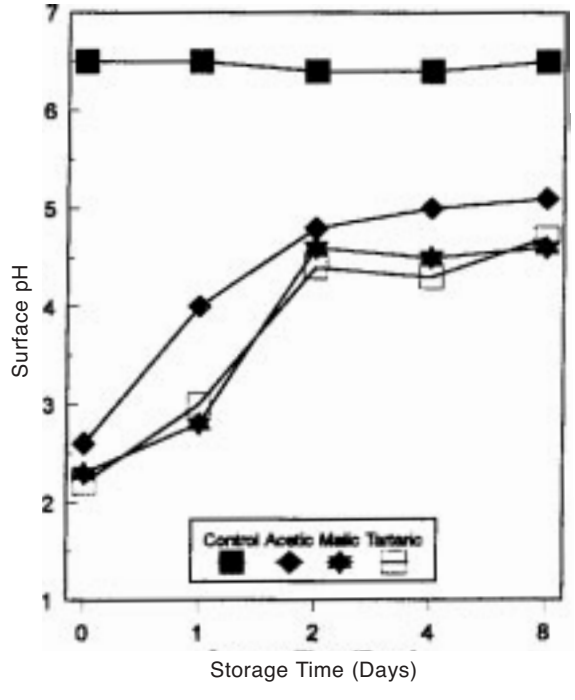


Figure 1. Change in surface pH of acid-treated catfish fillets during storage at 4°C.

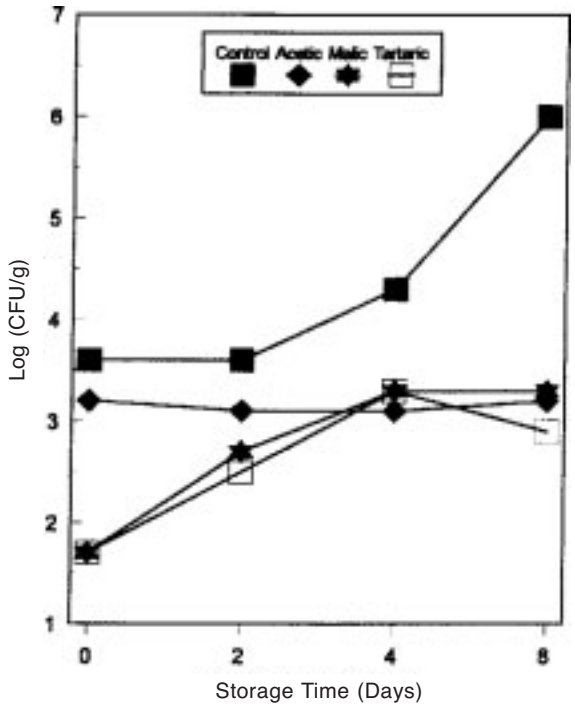


Figure 2. Change in aerobic plate counts of acid-treated catfish fillets during storage at 4°C.

undipped fillets had a significantly ($p<0.05$) firmer texture than acid-dipped fillets (Figure 3). Overall acceptability of broiled malic- and tartaric-acid-dipped fillets were comparable with controls (Figure 4), while acetic-acid-dipped fillets were scored less acceptable due to a lingering vinegar-like taste (Figure 4) at both day 0 and day 5. Panelists had no flavor objection to cooked fillets dipped with either malic or tartaric acid.

Compared with controls, raw catfish fillets were scored lighter in color ($P<0.05$) at all times during the study (Figure 5), while control fillets' color scores were not significantly different over the storage time ($P>0.05$). Freshness scores declined with storage time, but at all intervals, malic-acid-dipped fillets were considered fresher than the control and the other acid-dipped fillets (Figure 6).

Impact of color changes — Like earlier work (Silva and White, 1994), we found that fillet color was lighter as the surface pH was reduced. Lighter-colored catfish fillets may be of little consequence since this food is often battered and fried before consumption (Ingham 1989). However, if color proves to be an important consumer consideration, formulations with malic acid may provide the least color bleaching.

Conclusion

Organic acids may provide the cornerstone of sanitizing formulations or processing aids that can improve the microbiological quality and safety of catfish. Such treatments reduce the microbial loads and extend the shelf life of the product. Acid-dipped fillets may appeal to consumers concerned with the health risks of organochlorines.

Acknowledgments

We thank Cha Chi Koh and Juan J. Herrera for expert technical assistance. This work was supported in part by USDA Food Safety Cooperative Agreement #58-6202-0-001 and by the Mississippi Agricultural and Forestry Experiment Station under project MIS-0860.

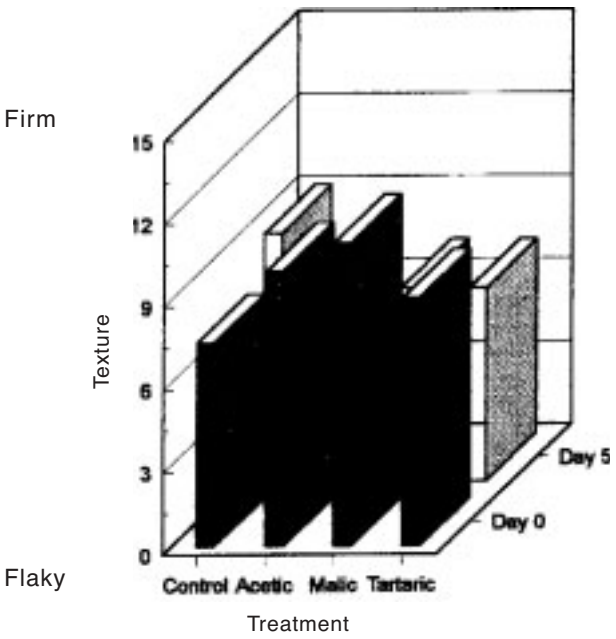


Figure 3. Sensory texture scores of broiled acid-treated catfish fillets.

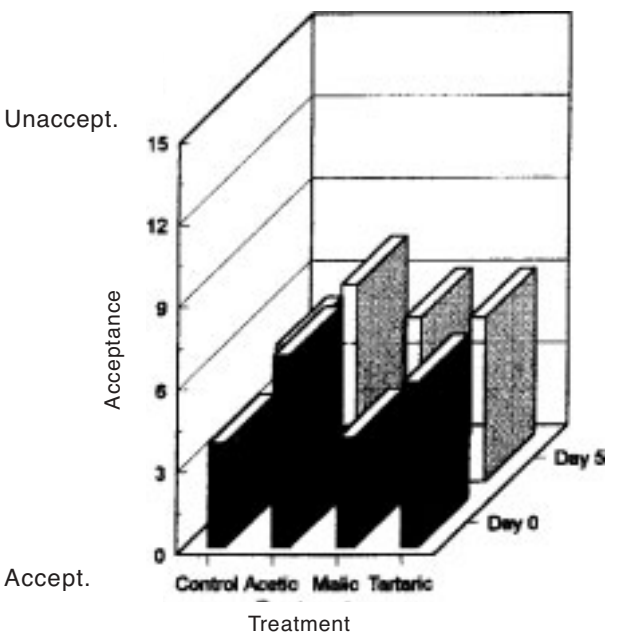


Figure 4. Sensory acceptability scores of broiled acid-treated catfish fillets.

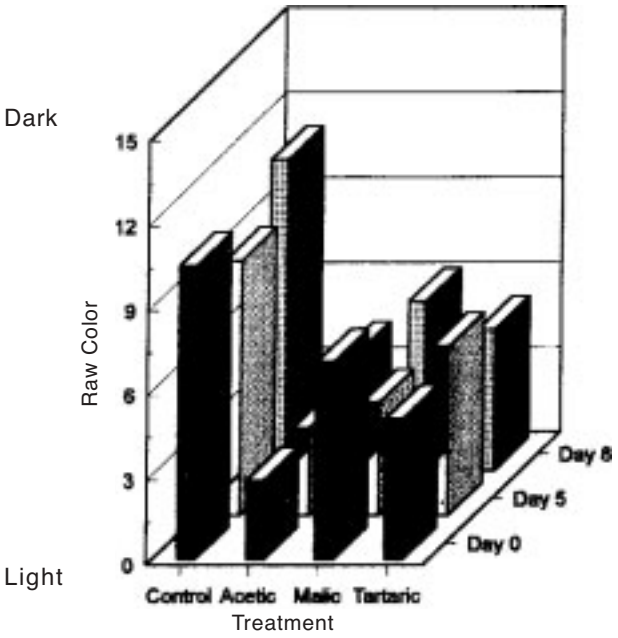


Figure 5. Sensory color scores of raw acid-treated catfish fillets.

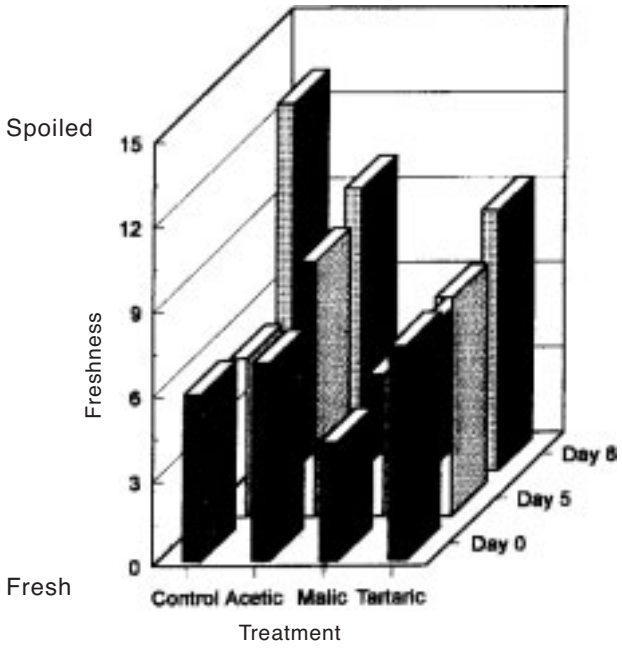


Figure 6. Sensory freshness scores of raw acid-treated catfish fillets.

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Storage Time and Temperature Effect on Catfish Frame Quality

Voranuch Suvanich and Douglas L. Marshall

Abstract

Chemical, physical, microbiological, and sensory changes of catfish frames stored at different times and temperatures were determined in terms of pH, Hunter color, aerobic plate counts (APC), total coliform counts (TCC), and quantitative descriptive analysis (QDA). Catfish frames stored at 25°C were considered microbiologically acceptable for 10.3 hours with APC reaching $\leq 10^7$ CFU/g or for 18 hours with TCC being $>10^6$ CFU/g; conversely, sensory storage life was limited to 6 hours. At 5°C, catfish frames had microbial acceptability for 3.5 days and sensory acceptability for 4 days, with a significant increase in TCC counts after 2 days. Catfish frames stored at 0°C had the longest storage life, up to 8 days, due to acceptable APC and sensory assessments. TCC of frames stored at 0°C declined. Hunter L- and Hunter b-values, as well as pH of catfish frames, did not change with storage time or temperature. There were linear correlations ($r > 0.9$) between microbiological and sensory changes. This study suggested that microbial numbers and sensory scores were good indicators of catfish frame quality.

Introduction

Channel catfish (*Ictalurus punctatus*) are the fourth most frequently consumed fish in the United States (Tucker and Robinson, 1990). About 75% of the total U.S. channel catfish production is in the state of Mississippi, where phenomenal growth in catfish production and processing has led to industrial development (Tucker and Robinson, 1990). Increasing amounts of catfish are filleted and further processed into value-added products for marketing (Anonymous, 1993). Traditional catfish processing focuses on fillets and whole dressed fish. The yield (dress-out) of catfish after whole fillet processing is about 45%, generating approximately 55% offal (McAlpin, 1993). In order to reduce postharvest losses, formed products could be produced from catfish by-products, such as frames from filleted fish. Frames are about 18% of the live weight of catfish. McAlpin (1993) stated that about 75% meat could be recovered from frames and trimmings that could be used for processing to value-added products such as surimi. In Mississippi, 25 million pounds of recovered meat could be used for this purpose per year (McAlpin, 1993).

Postmortem events after fish evisceration can cause sensory deterioration, autolytic increases, microbial proliferation, rancidity development, and physical changes that consequently reduce product quality (Huss, 1988). Each processing step may result in latent quality changes. These changes also can result from a delay in processing. For total quality control, final product quality is dependent on raw material quality (Regenstein and Regenstein, 1991). The term "spoilage" is defined as the time when catfish frames are no longer acceptable as raw material for human food or animal feeding (Regenstein and Regenstein, 1991). The major cause of fresh fish spoilage is bacterial decomposition (Huss, 1988). However, sensory evaluation is a routinely used method that gives the best idea of freshness or degree of spoilage and general acceptability (Pigott, 1988). Chemical methods have been proposed as indicators of freshness and spoilage, whereas physical methods are available commercially and give a reliable estimation of quality in a nondestructive manner (Huss, 1988).

There have been numerous studies on storage changes of filleted and/or minced fish including catfish mince (Chou, 1993), pollack (Scott et al., 1988), mackerel (Farragut, 1972), menhaden (Hwang and Regenstein, 1988), hake (Hiltz et al., 1976), and cod (Hastings, 1989). Based upon the concept of total quality control, storage changes of catfish frames should be evaluated prior to those of catfish mince. Nevertheless, there is little pertinent information addressing storage life and effects of storage time and temperature of catfish frames before processing to mince. The present study describes work that used different quality analyses to assess spoilage and storage life of catfish frames stored at three different temperatures. Each temperature mimicked commercial conditions during transportation, storage, and holding prior to processing frames to mince or rendering. Time limits during transportation, processing, storage, and abuse temperature were delineated.

Materials and Methods

Collection and sampling of catfish frames — For each experimental replication, approximately 100 channel catfish frames were collected after filleting, packaged in polyethylene bags, placed in ice, and transported from a commercial catfish processor to Mississippi State University. At the laboratory, frames were washed in tap water (28 ± 2EC) and packed in 1-gallon polyethylene bags (heavy-duty freezer Ziploc® bags) in duplicate and

stored at 0, 5, and 25 °C. Temperatures simulated ice-packed, refrigeration, and ambient conditions during transportation, storage, and processing to final products, respectively. Postmortem time until storage was approximately 3 ± 1 hours. Time after frames were washed and packed in storage bags was designated as "time 0."

Frames were sampled and evaluated for quality changes every 6 hours at 25°C and every 2 days at 5 and 0 °C. At each sampling time, eight frames were randomly removed from each storage temperature. Sampling continued until frames became spoiled as indicated by a strong offensive odor.

Measurement of pH — A modification of the procedure described by Scott et al. (1988) was used to measure frame pH. At each sampling time, duplicate catfish frames were ground and blended at high speed for 1 minute with deionized water (1:9 w/v) in a blender (Oster, Milwaukee, Wisconsin). Homogenate pH was measured using a standardized portable pH meter (Model Acumet 1001, Fisher Scientific).

Measurement of color — Color of catfish frames was measured using a Hunter Color Labscan 6000 0/45° Spectrocolorimeter (Hunter Associates Laboratory, Reston, Virginia). Color was expressed in terms of lightness (L value), redness (a value), and yellowness (b value) (Hunter, 1975). Standardizations were made with both black and white plates (Standard No. LS-13601, L_o = 92.21, a_o = -0.91, b_o = -0.36). Hunter values were the average of seven readings from different locations on a frame along its vertebral column and the remaining area of the frame using a 3.81-centimeter diameter view. Two frames from each storage temperature were used per sampling time.

Enumeration of microorganisms — A catfish frame (~90 g) was placed in a sterile stomacher bag and shaken manually with 1:1 (w/v) 0.1% sterile peptone (Difco, Detroit, MI) diluent for 1 minute. Subsequent serial dilutions were prepared in 0.1% peptone solution. One milliliter of each dilution was plated onto Petrifilm™ aerobic count plates (3M, St. Paul, Minnesota) for aerobic plate counts (APC) with incubation at 32°C for 48 hours. Similarly, total coliform counts (TCC) were estimated using Petrifilm™ coliform count plates (3M) with incubation at 32°C for 24 hours (APHA, 1992). Both tests were performed on two frames from each temperature per sampling time. Colony counts were recorded, converted to $\log_{10}$ CFU/g, and analyzed for time and temperature effects using SAS (SAS, 1988).

Sensory evaluation — At each sampling time, random catfish frames were removed from each storage temperature and placed into new Ziploc® bags. Each bag was coded with three-digit random numbers. The quantitative descriptive analysis (QDA) method of Stone et al. (1974) was modified for sensory analysis. Raw catfish frames were evaluated by a six-member trained panel. Criteria for recruitment were that they (1) regularly consumed catfish, (2) were willing to evaluate spoiled fish, (3) had some background with the QDA technique, (4) were selected from a pool of 10 panelists for their ability to discriminate sample attributes, and (5) were available and willing to participate during training and testing dates. Panelists were trained for 2 days for at least 2 hours each day. During training, panelists were presented with several frames, representing various degrees of deterioration, to define changes in each attribute (i.e. color, appearance, and odor). Terminology characterizing sensory attributes was developed from Huss (1988) and Pigott (1988) and from panelist's opinions while training. Final lists of attributes with definitions (Table 1) were chosen by consensus of panelists.

Table 1. Catfish quantitative descriptive analysis (QDA) profile definitions

Terms	Definitions	Criteria	
		Good Quality (0-cm)	Poor Quality (10-cm)
Vertebral column appearance	Degree of attachment of supporting axis of the frame to flesh	Break instead of easily detaches	Not attached or easily detaches
Flesh appearance	Outward appearance of soft tissue on surface of the frame	Bluish, translucent, smooth, or shiny	Dull or opaque
Color of flesh along vertebral column	Pigmentation of flesh near vertebral column	No change in actual color (agar-like color)	Red or dark brown
Off-odor	Exhibiting off/abnormal smell	Aromatic, associated with raw and fresh water fish	Strong abnormal odor such as mousy, bready, sour, or rancid
Spoiled odor	Exhibiting deteriorated/putrid smell	Characteristic of species, aromatic, associated with raw and fresh water fish	Strong odor such as stale cabbage, ammonia, or sulfides
Overall quality	Taking everything into consideration; panelist's rating of degree of excellence for essential character of samples	Good overall appearance and aroma	Bad overall appearance and aroma
Acceptability	Adequate for human or animal food		

Source: Modified from Huss (1988) and Pigott (1988)

Ten-centimeter unstructured line scales without anchors were used for rating attribute intensities. Panelists marked each scale on their questionnaires to indicate intensity. Samples were evaluated for changes in freshness and spoilage based on several factors: (1) appearance — vertebral column (attached to detached), flesh (translucent to opaque), color along vertebral column (normal color of fish flesh to red/dark brown); (2) odor — off-odor such as stale, algae, cabbage-like, or mud-like odor (no off-odor to strong off-odor) and spoiled odor such as fishy, hydrogen sulfide, or ammonia (normal odor to spoiled odor); and (3) overall quality (acceptable to unacceptable). Frames were considered spoiled when they had strong odor, detached vertebral columns, opaque flesh, red or dark brown color along vertebral columns, and looked unfit for human consumption or animal feeding (Huss, 1988).

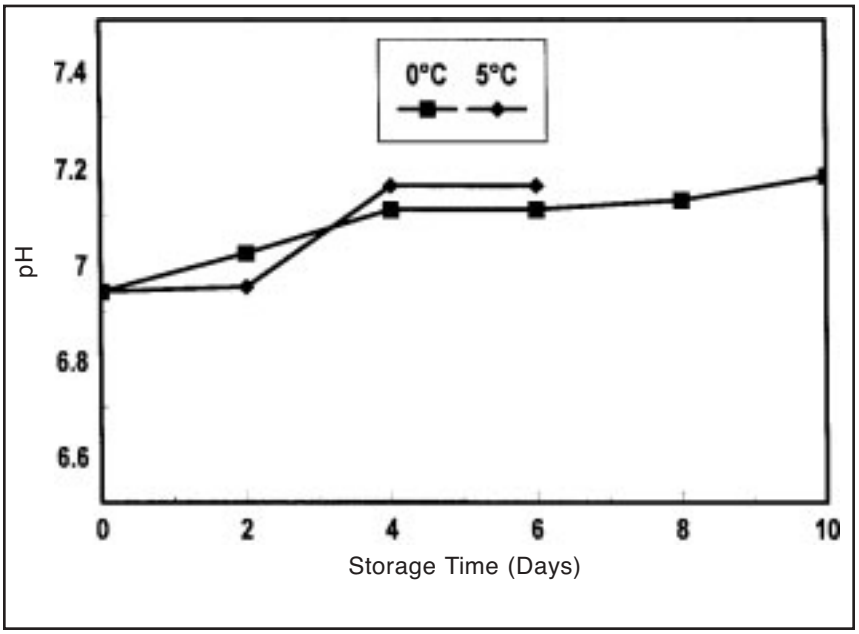
Statistical analysis — A randomized complete block design (RCB) was used with three replicate experiments and two duplicate samples (catfish frame) per experimental unit per sampling time. Experiments were a series of repeated measures taken for the three storage temperatures over different time periods. General linear model (GLM), correlation analysis, and comparison of least significant different means (used for variables that were measured) for time and temperature were done using SAS (SAS, 1988). Means were separated by least significant difference test at 0.05 probability level (Steel and Torrie, 1980; SAS, 1988).

Results and Discussions

Change in pH — Fresh catfish frames had a pH of 6.95, which did not change over 18 hours of storage at 25°C (data not shown). There was a significant increase in pH of frames stored at 5 and 0 °C during the first 4 days of storage, after which no change occurred (Figure 1). The pH of live fish muscle tissue is close to neutrality (Huss, 1988). Pedrosa-Menabrito and Regenstein (1988) stated that the pH was dependent upon fish species, which was usually between 6.2 and 6.5 immediately after rigor mortis. Lactate formed from glycolysis in the postmortem muscle tissue lowers pH on the first day after death even at a temperature just below 0°C (Whittle et al., 1990). After glycolysis, autolytic changes, such as breakdown of proteins, provide an optimum condition for growth and reproduction of spoilage microflora, which can produce amines raising the product pH (Parkin and Brown, 1983; Pedrosa-Menabrito and Regenstein, 1988). However, Etherington (1984) reported no change in pH in capeline (*Mallotus villosus*) during storage. In the present study, increased pH at low temperature may have been due to enzymatic activity resulting in proteolysis and formation of alkaline compounds. In addition, increased pH could be due to psychrotrophic microbial growth whose metabolic by-products may be alkaline (Parkin and Brown, 1983; Etherington, 1984; Huss, 1988; Pedrosa-Menabrito and Regenstein, 1988).

Change in color — Hunter L-values of frames stored at 25°C slightly decreased after 12 hours from the original level (Figure 2A); however, there were no L-value changes of catfish frames during storage at 5 (Figure 2B) and 0 °C (Figure 2C). Hunter L-values not only measure lightness of products, but also take into account their shininess or dullness. With catfish, high Hunter L values are due to increased shininess (Hoke, 1993). Shininess and glossiness correlate with product freshness and fat content. Thus, the small decrease in Hunter L-value of stored frames at 25°C could be due to autolytic or microbial lipolysis.

Trends of redness (a) value of frames stored at 25, 5, and 0 °C were the same. Redness of frames stored at 25°C increased the first 6 hours of storage then decreased after 12 hours to a value that was lower than time zero (Figure 2A). Figure 2B shows that redness of



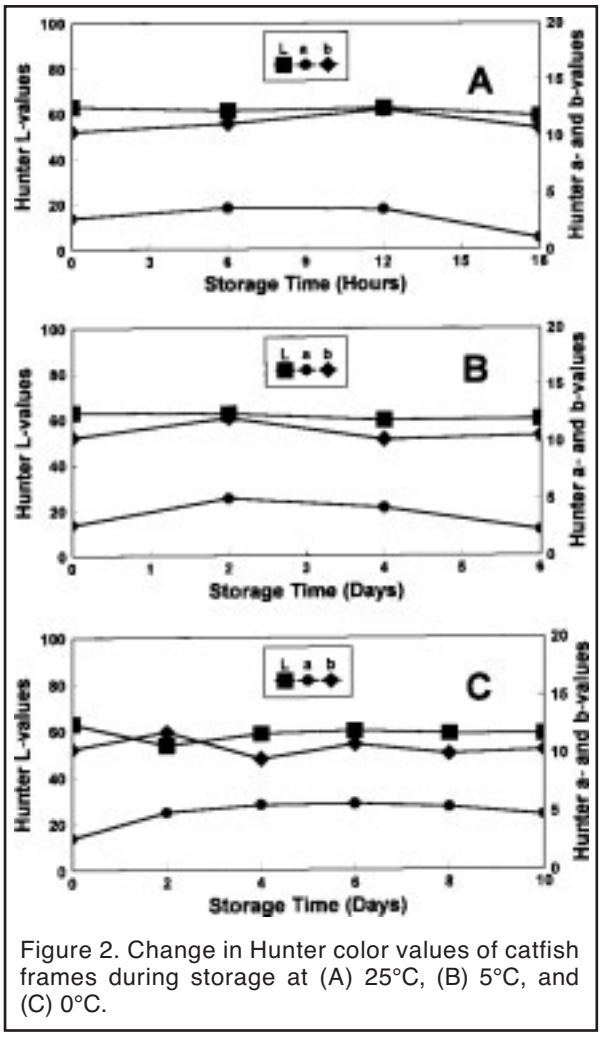


Figure 2. Change in Hunter color values of catfish frames during storage at (A) 25°C, (B) 5°C, and (C) 0°C.

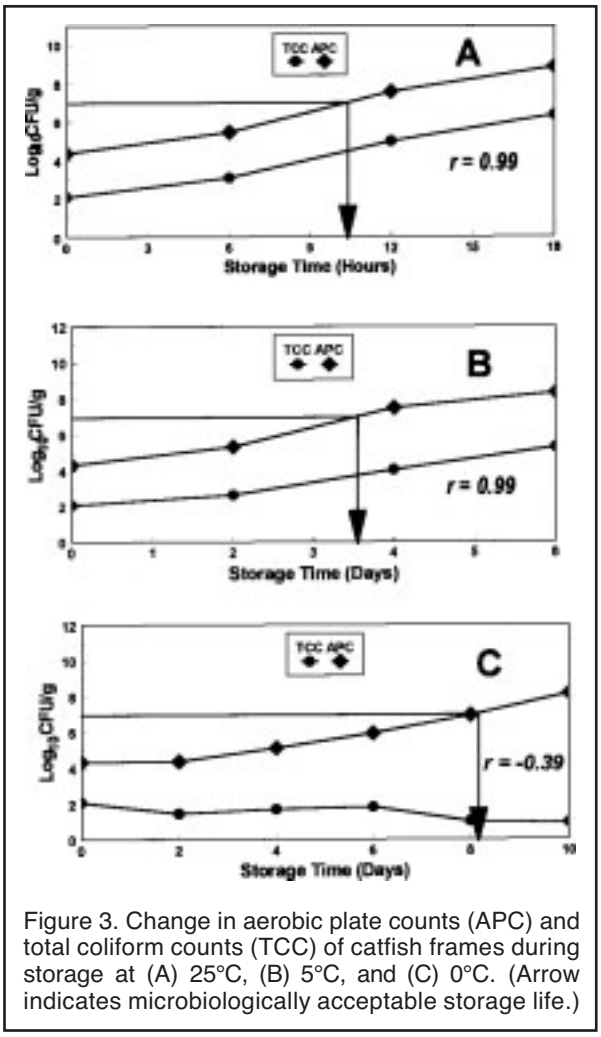


Figure 3. Change in aerobic plate counts (APC) and total coliform counts (TCC) of catfish frames during storage at (A) 25°C, (B) 5°C, and (C) 0°C. (Arrow indicates microbiologically acceptable storage life.)

frames stored at 5°C increased during the first 2 days of storage then decreased until the end of storage to the original level. Redness of frames stored at 0°C increased up to day 2 and thereafter remained unchanged (Figure 2C). Livingston and Brown (1981) stated that heme pigments associated with red color on the surface of fish meat include oxymyoglobin, oxyhemoglobin, and hemoglobin. Hemoglobin can be lost easily during handling and storage, while myoglobin is retained by the intracellular muscle. Dark muscle of fish contains high myoglobin concentrations and is normally concentrated along the side of fish bodies (Hultin, 1992). Discoloration of fish during storage is associated with formation of metmyoglobin, the oxidation product of myoglobin, which is an initiator of lipid oxidation in the presence of H_2O_2 (Tichivangana and Morrissey, 1985; Hultin, 1992). Fish myoglobins are more sensitive to autoxidation than mammalian myoglobins, with oxidation becoming greater as temperature increases and pH decreases (Govindarajan, 1973; Livingston and Brown, 1981). In the Hunter color system, a-value refers to color intensity ranging from greenness (-a) to redness (+a) (Hunter, 1975). Oxidation of the heme pigments during storage of catfish results in a shift from red toward green hues (Woodroof, 1987). Moreover, oxidation of other pigments can contribute to the decrease in Hunter a values over time (Hoke, 1993). Therefore, the increase in darkness of catfish frames along the vertebral column was likely due to methemoglobin formation from decomposition of abundant marrow hemoglobin and autoxidation of muscle myoglobin, which also resulted in a redness decrease during storage.

Yellowness (Hunter b values) of frames stored at 25°C increased during 12 hours and then significantly decreased (Figure 2A). Yellowness of frames stored at 5 (Figure 2B) and 0 °C (Figure 2C) increased significantly up to day 2, then decreased and remained

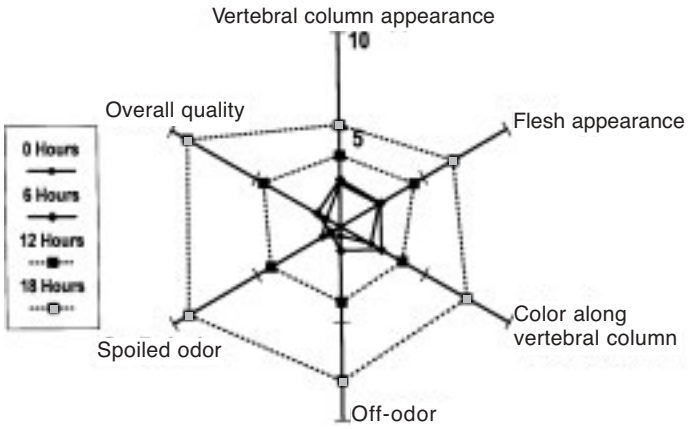


Figure 4. Quantitative descriptive analysis profile of catfish frames during storage at 25°C (solid line responses are significantly different from dotted line responses.)

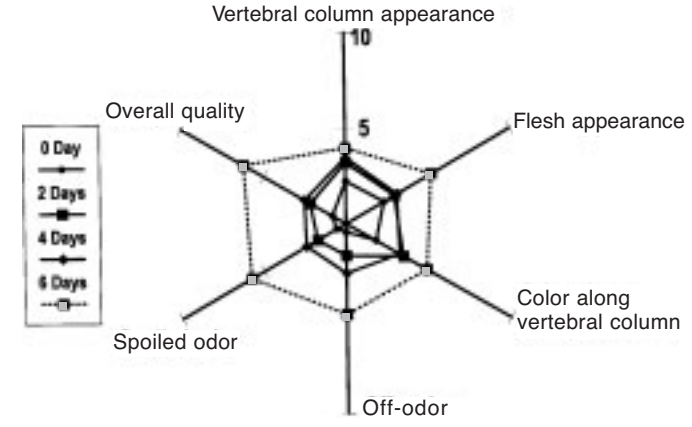


Figure 4. Quantitative descriptive analysis profile of catfish frames during storage at 5°C (solid line responses are significantly different from dotted line responses.)

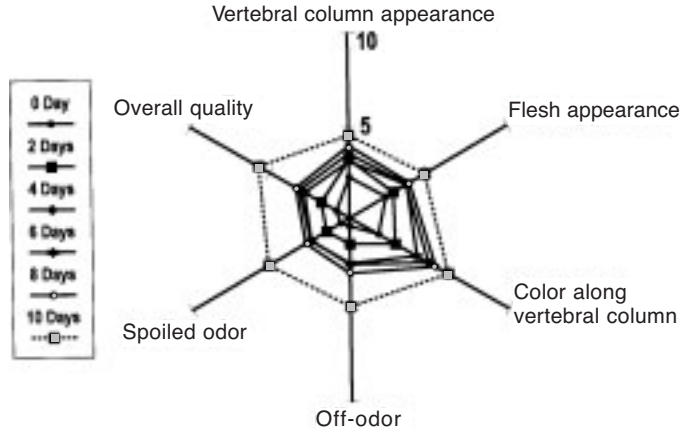


Figure 4. Quantitative descriptive analysis profile of catfish frames during storage at 0°C (solid line responses are significantly different from dotted line responses.)

unchanged from the original level. Furthermore, there was no difference between b values of the frames stored at both temperatures. Hunter b value denotes blueness (-b) to yellowness (+b) (Hunter, 1975). Lipid oxidation and carbonyl-amine reactions can increase fish flesh yellowness (Haard, 1992). In addition, spoilage bacteria (e.g., *Enterobacter cloacae* and *Pseudomonas* sp.) can convert glucose to 2,5-diketogluconic acid, which can react with amino acids or proteins to form brown colored products (Haard, 1992). Therefore, brown discoloration may have masked flesh yellowing of catfish frames during later stages of storage resulting in decreased yellowness during storage. These results confirm those of Hoke (1993), who noted that catfish frame mince became less yellow and more blue during storage. Color, especially whiteness, is one of the most important marketing attributes of surimi products (Regenstein and Regenstein, 1991). Thus, Hunter color values of catfish frames, which are raw material for surimi, are important. Use of poor-quality frames as a raw material can result in an unacceptable finished product to consumers.

Microbiological analysis — Initial APC of fresh catfish frames before storage were approximately 10^4 CFU/g. APC increases of frames stored at 25°C (Figure 3A) gave an estimated storage-life (time to reach 10^7 CFU/g for acceptability of freshwater fish) of 10.3 hours as recommended by ICMSF (1978). Initial TCC on fresh catfish frames before storage were about 10^2 CFU/g. Similar to APC, TCC increased during storage at 25°C, reaching over 10^6 CFU/g by 18 hours of storage (Figure 3A). APC significantly correlated ($r = 0.99$) with TCC at 25°C.

Like trends at 25°C, APC of frames stored at 5°C increased after 2 days of storage (Figure 3B). Frames stored at 5°C had an estimated shelf life of 3.5 days. APC of frames stored at 0°C did not change during the first 2 days of storage, but it increased significantly during the remaining storage period (Figure 3C). Frames stored at 0°C remained microbiologically acceptable up to day 8.

At 5°C, TCC of catfish frames significantly increased after 2 days of storage (Figure 3B); however, TCC of frames at 0°C gradually decreased during storage (Figure 3C). Final TCC of frames stored at 0°C were lower than initial counts. This finding suggested that storage temperature of 0°C could retard coliform growth.

Correlation between TCC and APC of frames stored at 5°C was 0.91; however, there was poor correlation (r = -0.39) at 0°C. Thus, the APC increase at 0°C did not indicate increased risk of enteric pathogens. Coliforms are gram-negative bacteria used as indicators of sanitation and product safety because they can be recovered more easily than enteric pathogens such as *Salmonella* (APHA, 1992).

Sensory evaluation — Panel scores were analyzed, taking into account time-to-time variation of each temperature and individual panelist bias. QDA profiles of catfish frames stored at 25, 5, and 0 °C were plotted as spider web charts using resulting mean scores for each storage time on each attribute scale (Figures 4-6).

QDA profile indicated that quality of frames stored at 25°C did not change significantly during the first 6 hours of storage (Figure 4). After 6 hours, frames began to lose their natural sheen, the flesh turned dull, the color along to vertebral column became darker red, and strong off-odor and spoiled odor were detected. Further storage to 18 hours led to opaque flesh, dark red color along the vertebral column, and strong malodor. Overall quality was classified as unacceptable after 6 hours.

QDA profiles showed that the quality of catfish frames stored at 5 (Figure 5) and 0 °C (Figure 6) did not change noticeably during the first 4 and 8 days of storage, respectively. Off-odor and spoiled odor were detected at 6 days for frames stored at 5°C and at 10 days at 0°C. Similar to the characteristic of offensive odor, results of overall quality and acceptability of the frames stored at 5 and 0 °C were similar (Figures 5 and 6). Moreover, QDA results showed no difference between the majority of the characteristics of the 4-day frames stored at 5°C and 8-day frames stored at 0°C. Other reports stated that a well-maintained storage condition of 0°C can extend time prior to processing catfish for up to 4 days (Chou, 1993).

QDA profiles demonstrated that vertebral column appearance, flesh appearance, and color along vertebral column parameters were not as good as offensive odor (spoiled and off-odor) and overall quality parameters to determine catfish frame quality. Highest correlation between acceptability and each sensory parameter was with off-odor (r = 0.95) and spoiled odor (r = 0.96). Visual parameters, such as flesh appearance (r = 0.92) and color along the vertebral column (r = 0.84), were less correlated. These results implied that odor was the best indicator of fresh catfish frame acceptability.

Conclusions

Decreases in quality of stored catfish frames at different temperatures coincided with increases in microbial counts and QDA profiles. There was a linear correlation between microbiological counts and QDA scores ($r > 0.9$). QDA was not correlated with pH and Hunter color values during storage. Likewise, pH and Hunter color measures were poorly correlated with acceptability over time ($r \leq 0.4$ and $r \geq -0.5$, respectively). Sensory evaluation (QDA), especially offensive odor, in conjunction with microbiological tests would provide an adequate assessment of catfish frame quality.

Refrigerated storage at 5°C, rather than 0°C, is recommended for reduced cost during storage or transportation of frames to processing plants unless transportation or storage time is longer than 4 days. Holding and handling of catfish frames should not be longer than 6 hours at an abusive storage temperature of 25°C.

Since raw material quality is important for final product quality, storage, processing, and distribution times and temperatures are important. Results of this study can be used to predict shelf life of catfish frames at different temperatures (25, 5, and 0 °C). Catfish frames can be further processed to mince for value-added products. Better utilization of catfish frames can be achieved by proper control of time and temperature for total quality control.

Acknowledgments

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Microflora of Catfish Processing Equipment Surfaces

Lori N. Cotton and Douglas L. Marshall

Abstract

Eighty-eight gram-negative and nine gram-positive bacterial isolates from swab samples of equipment surfaces taken from two catfish processing plants over two replications were identified using the Vitek Identification System and commercially available rapid biochemical kits. Pseudomonas spp. and Aeromonas spp. represented 38% of the identified gram-negative isolates. Samples taken from conveyors yielded greatest microbial diversity. There were differences between plants in terms of predominant bacterial types, with identified isolates from the larger, automated plant being mostly pseudomonads (48%), while 57% of the identified gram-negative isolates from the smaller, manually operated plant were aeromonads. That pseudomonads predominate in the large, automated plant indicates more effective or frequent equipment sanitization. Therefore, Aeromonas spp. could be used as an indicator of inadequate sanitation in catfish processing plants.

Objectives

- To identify the predominant types of bacteria on catfish processing equipment.
- To identify processing areas likely to harbor spoilage or disease-causing bacteria.

Description of Sampling Procedures

Plant 1 was a small, manual catfish processing facility. From this plant, a total of 20 environmental swab samples was taken: nine from the deheader, seven from the conveyors, two from the evisceration tubes, and two from cutting boards.

Plant 2 was a large, automated catfish processing facility. From this plant, a total of 19 environmental swab samples was taken: four from the deheader; six from the conveyors; two from the automated filleting machines; two from the cutting boards; and five from the chill tank.

Results and Discussion

Identified gram-negative isolates differed between processing plants (Figure 2). Isolates from environmental samples taken at Plant 1 were largely aeromonads (57%), while pseudomonads represented 28%. Gram-negative isolates from Plant 2 were mostly pseudomonads (48%), with Aeromonas species representing 17%. Figure 3 illustrates the number of *Aeromonas* and *Pseudomonas* isolates for each swabbing site at Plants 1 (A) and 2 (B).

Differing predominant microflora between Plants 1 and 2 were present for both replications conducted during late winter to early spring (first replication) and late spring to early summer (second replication). Therefore, no seasonal variation was observed. Coliforms and gram-positive bacteria comprised a minor portion of the identified isolates. Gram-positive microflora characterization, which was done at Plant 2 during the first replication, showed that most isolates were cocci and located on conveyors. Importantly, *Listeria monocytogenes*, *Salmonella*, and other enteric pathogens were not isolated in this study.

The plants surveyed in this study differed in process flow. Watchalatone (1996) determined that process flow influenced microflora of channel catfish fillets. This fact would not explain differences between Plants 1 and 2 in predominating microflora of, for example, deheaders, since this station was first in both process flows. The difference in microbial predominance between Plant 1

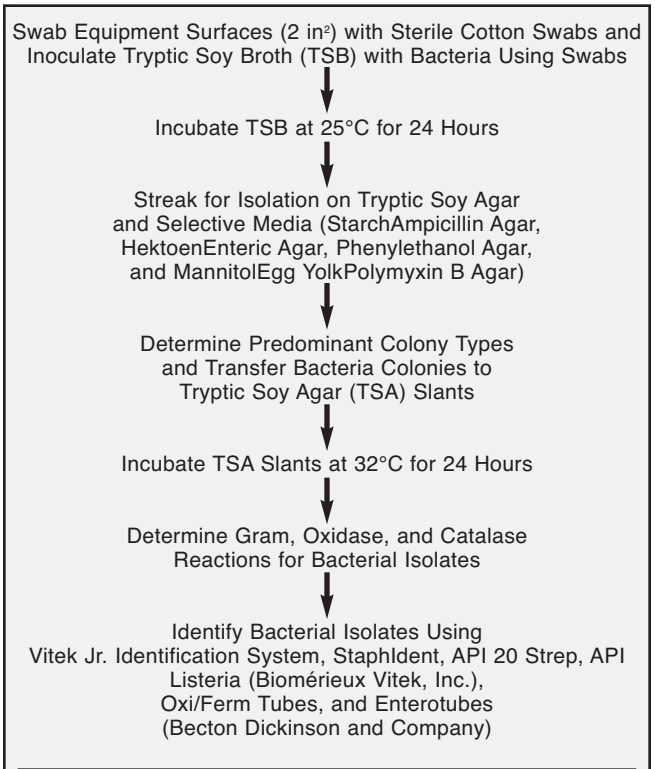

Figure 1. Diagram of experimental procedure used to isolate and identify bacterial isolates from environmental swab samples taken at two catfish processing plants (two replications).

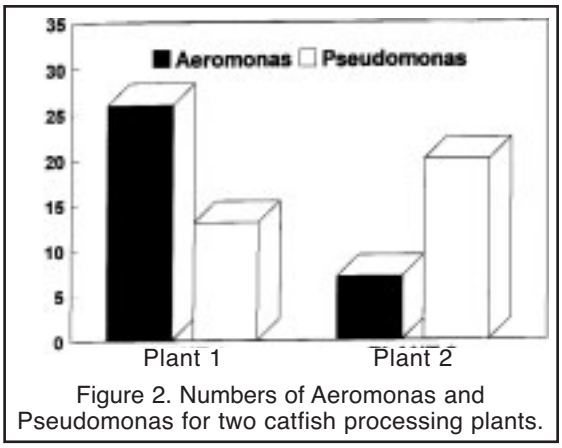

Figure 2. Numbers of Aeromonas and Pseudomonas for two catfish processing plants.

and 2 may be related to differences in sanitation practices. Nuñez (1995) reported that larger, automated plants manufactured catfish fillets with lower microbial numbers than smaller, manually operated plants possibly due to superior sanitation.

Differences in environmental microflora between plants reported in the present study also may be due to more efficient use of sanitizers. The plants surveyed in this study differed in their sanitizing regimens. Employees in Plant 1 cleaned and sanitized equipment at the close of processing, while those in Plant 2 sprayed sanitizer on equipment surfaces during employee break periods in addition to cleaning and sanitizing after processing. In studies comparing species of bacteria in untreated and chlorinated distribution waters, Armstrong et al. (1981, 1982) reported that the incidence of pseudomonads and related bacteria increased, while the percentage of aeromonads and other gram-negative, fermentative rods decreased. Frequent sanitizing with chlorinated agents may select for predominance of pseudomonads on processing equipment surfaces. Predominance of *Aeromonas* could indicate ineffective sanitation of catfish processing equipment.

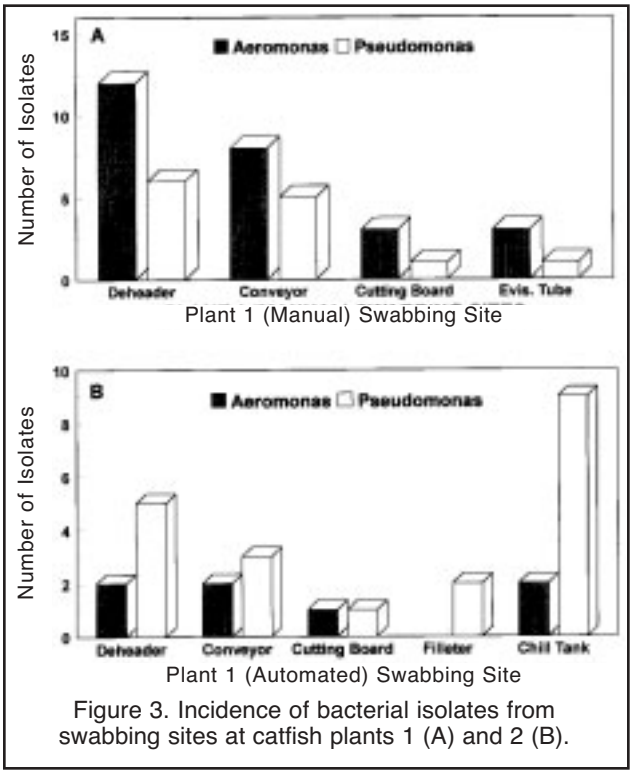

Figure 3. Incidence of bacterial isolates from swabbing sites at catfish plants 1 (A) and 2 (B).

Conclusions

Overall, with both plants combined, the largest percentages of the 88 identified gram-negative isolates were pseudomonads (38%) and aeromonads (38%), followed by enterics (18%) (Family *Enterobacteriaceae*), including coliforms. Bacteria identified on catfish processing equipment would not likely constitute a food safety concern, with the possible exceptions of *Aeromonas hydrophila* and *Edwardsiella tarda* (1%). That pseudomonads predominate in the large, automated catfish processing plant indicates more effective or frequent equipment sanitization.

Acknowledgments

The authors thank the catfish processing plants participating in this study and Dr. C.L. Wang for use of the Vitek Identification System. Mary Scruggs provided expert Vitek training. Dr. Vineet Jindal and Voranuch Suvanich also are thanked for laboratory assistance. Support for this study was provided by USDA Special Grant No. 91-34231-5940 and by the Mississippi Agricultural and Forestry Experiment Station under project MIS-0891.

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Analysis of Off-Odors in Water from Mississippi Catfish Ponds

Casey C. Grimm, Steven W. Lloyd, Christopher P. Dionigi, and Jeanne Moore

Introduction

Geosmin and 2-methylisoborneol are two very potent compounds that are absorbed by farm-raised catfish from the surrounding pond water. These compounds are discernible by the human nose when present in concentrations of 30-40 parts per trillion (ppt), and they can render catfish unfit for marketing when present in fish tissue at concentrations greater than about 700 ppt. A rapid method for the analysis of geosmin and 2-MIB has been developed for determining their concentrations in water. Solid-phase microextraction (SPME) is used in conjunction with gas chromatography and flame ionization detection to determine concentrations down to 100 ppt.

Water samples were taken from 10 separate ponds located at the Delta Research and Experimental Station in Stoneville, Mississippi. Samples were collected on August 21, 1996, placed in 20-milliliter vials, capped, and refrigerated until analyzed. The initial analysis was run on August 28, and replicate analyses were run during the first and second weeks of September.

Results

The concentrations of geosmin and 2-MIB in water can be determined from 30 parts per billion (ppb) down to 0.1 ppb using SPME/GC/FID. The relative standard deviation (RSD) varies from 8% to 19% for geosmin and is similar for 2-MIB with one exception (Figure 1). The RSD for 2-MIB at 0.1 ppb is 148%, indicative of the limit of detection.

For the Mississippi pond water, 2-MIB was found only in pond 26 at a concentration of 35 ppb ± 6 ppb (Figure 2). No geosmin was observed in any of the ponds within experimental error; however, pond 5 and pond 28 showed slight traces, but repeated runs failed to detect any geosmin.

The total analysis time to run a sample of the pond water was 35 minutes — 5 minutes for adsorption onto the SPME fiber and a 30-minute chromatographic run. The chromatographic run has been shortened to 10 minutes for a total analysis time of 15 minutes per sample (Figure 2).

Conclusions

The methodology described here is relatively rapid and of low cost compared with current analytical methodology. It is economically feasible and is a robust technology that can be easily moved from the laboratory to the field for implementation. The analysis of pond water could be used to monitor the state of a pond following an algae bloom. However, the relationship of the concentrations of geosmin and 2-MIB between pond water and catfish is dependent upon several factors including size and fat content of the catfish. We intend to perform field studies to determine this relationship and the practicality of using this method.

- Portable gas chromatographs are commercially available, and a mobile unit could be developed for site visits.
- Water samples could be collected and analyzed at a central facility.
- The system could be automated to improve repeatability but at added expense.

Acknowledgments

We would like to thank Craig Tucker of Mississippi State University, and Dave Millie and Paul Zimba of SRRC for their assistance in water sample collections.

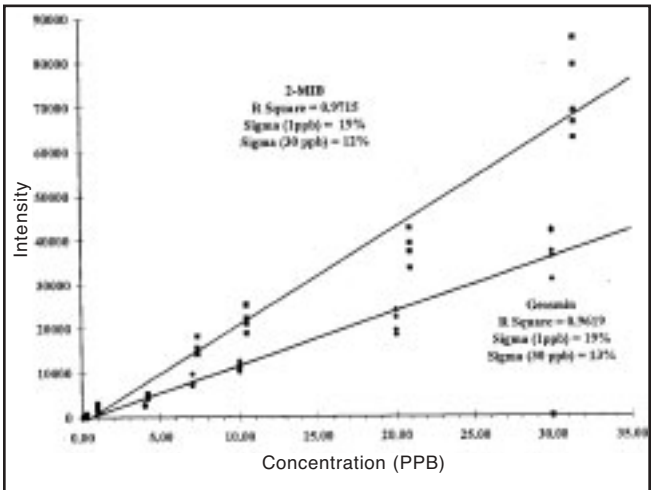


Figure 1. Standard calibration curves.

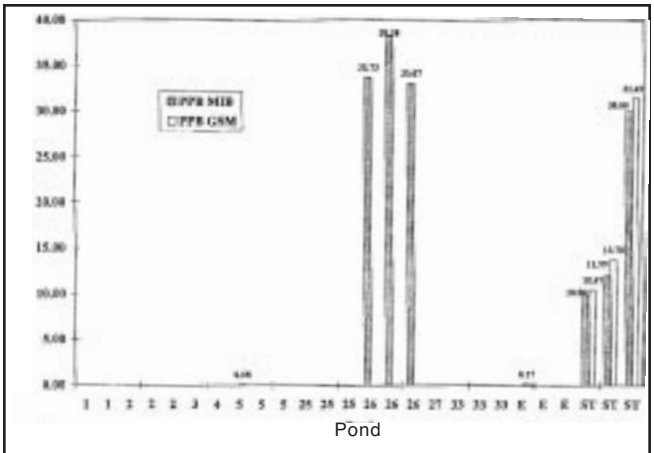


Figure 2. Concentration of 2-MIB and geosmin in pond water.

Analysis of Geosmin and 2-Methylisoborneol in Pond-Raised Catfish

Casey C. Grimm, Steven W. Lloyd, and Christopher P. Dionigi

Introduction

Geosmin and 2-methylisoborneol (2-MIB) — two ubiquitous compounds that are produced by algae, fungi, and bacteria — are a major cause of off-flavors in farm-raised catfish. These compounds render fish unfit for marketing when present at concentrations greater than ~0.7 ppb. A rapid method for the analysis of geosmin and 2-MIB has been developed to determine their concentrations in catfish.

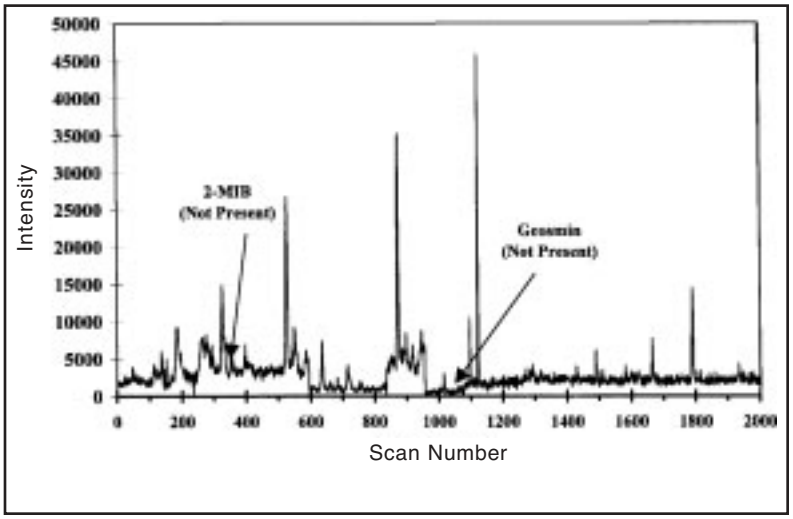
An on-line purge and trap is combined with a gas chromatograph-mass spectrometer for the unequivocal identification and quantitative analysis of geosmin and 2-MIB. The catfish is shredded in a blender, and 10 grams of tissue is sparged with helium for 10 minutes. Volatiles and semivolatiles are trapped on Tenax during the purging. The trapped volatiles are released onto the head of a GC column during a 2-minute thermal desorption. The compounds are eluted at specific times during a 30-minute temperature program of the GC. The mass spectrometer is operated in selected ion mode and the molecular ions and base peaks of each compound are monitored.

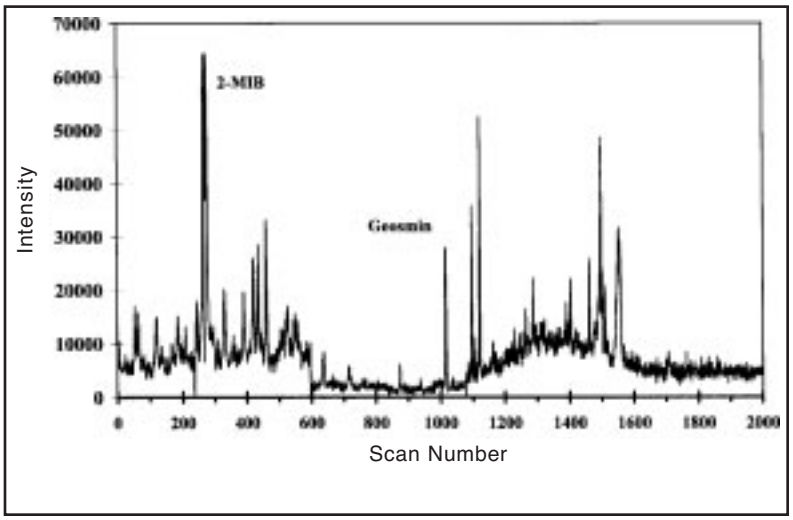
Results

A catfish fillet from Cargill pond 110, considered by a taste test to be "on-flavor" was analyzed for geosmin and 2-MIB. There was no 2-MIB observed; however, a trace level of geosmin was observed (Figure 1). A second catfish fillet, considered to be "off-flavor," from Cargill pond 112 was analyzed, and both geosmin and 2-MIB were observed (Figure 2). The molecular ions were not observed under SIM conditions. The compounds were identified by their retention time and the base peaks, m/z 95 for 2-MIB and m/z 112 for geosmin. The off-flavor fish contained about 10-20 ppb of geosmin and 2-MIB each. The spiking of shredded catfish in water with geosmin and 2-MIB standards results in a lower limit of detection of about 2.5 ppb. This is an order of magnitude too high for a useful technique (Figure 2).

Conclusions

The extraction, separation, and identification of extremely small quantities of geosmin and 2-MIB from catfish can be performed in less than an hour from start to finish. Currently, concentrations of geosmin and 2-MIB can be detected down to the 2.5 ppb level. Improved methodology utilizing the existing equipment should result in an analysis time approaching 10 minutes and a sensitivity of less than 0.1 ppb.





Listeria monocytogenes **in Raw, Heat-set, and Precooked Coated Channel Catfish Strips Under MAP**

Jaheon Koo, Juan L. Silva, and T. C. Chen

Channel catfish (*Ictalurus punctatus*) is sold mainly as fresh or frozen fillets or as dressed fish. However, there is an increased interest in heat-set or precooked coated products, for their added value and convenience. These products, if contaminated, are a major safety risk for consumers. The FDA has a zero tolerance for *Listeria monocytogenes* in precooked foods. The objective of this work was to monitor the behavior of *L. monocytogenes* on coated, heated catfish strips.

Raw (uncoated), heat-set (deep-fat fried for 45 seconds at 375°F), and precooked (deep-fat fried for 3.5 minutes at 375°F) battered and breaded channel catfish strips (50 grams) were inoculated with approximately 10^3 CFU/g of *L. monocytogenes* strain Scott A, placed in B700 barrier bags, vacuumized, and backflushed with 90% CO_2, 2.5% O_2, and 7.5% N_2 (MAP). They were held at 2°C (35.6°F), and analyzed for PPC, APC, and *L. monocytogenes* every 3 days for 12 days. Heat-set and precooked strips were reheated (baked) for 10 minutes and 30 minutes at 400°F in an oven, respectively.

Aerobic (APC) and psychrotrophic plate counts (PPC) of raw fillets increased ($P \leq 0.05$) by 2-2.5 log CFU/g over 12 days and were consistently higher ($P \leq 0.05$) than those of heat-set and precooked strips. Heat-set and precooked strips had 1-2 log CFU/g increase ($P \leq 0.05$) of aerobic and psychrotrophic plate counts during 12 days at 2°C. This indicates that the raw fillets had a shelf life of ~10 days, while the heat-set and the precooked products had at least double that shelf life (with precooked products having a longer shelf life, potentially). However, there was no *L. monocytogenes* growth ($P > 0.05$) in any of the treatments under MAP during 12 days of storage. Precooked strips had lower ($P \leq 0.05$) *L. monocytogenes* counts than heat-set strips, with raw strips having the highest ($P \leq 0.05$) counts. There was no microbial growth, including *L. monocytogenes*, after heat-set and precooked strips were reheated.

This study shows that *L. monocytogenes* did not grow in heat-set and precooked products, and that reheating or cooking by the consumer will eliminate any *Listeria* present on the product. However, it should be emphasized that the best control is to prevent the presence of *Listeria* on the product by following the adequate GMPs and SSOPs.

Staphylococcus aureus in Heat-set and Precooked Coated Channel Catfish Strips Under MAP

Jaheon Koo and Juan L. Silva

Heat-set (deep-fat fried for 45 seconds at 375°F) and precooked (deep-fat fried for 3.5 minutes at 375°F) battered and breaded channel catfish (*Ictalurus punctatus*) strips (50 grams) were inoculated with approximately 10^4 CFU/g of *Staphylococcus aureus*, placed in B700 barrier bags, vacuumized, and back-flushed with 90% CO_2, 7.5% N_2, and 2.5% O_2 (MAP), and in Ziploc freezer bags (AIR), respectively. Packaged strips were stored at 2°C. They were analyzed for aerobic (APC) and psychrotrophic (PPC) plate counts, as well as *S. aureus*, every 3 days for 12 days. Before analysis, heat-set and precooked strips in AIR were reheated (baked) for 30 minutes and 10 minutes at 400°F in an oven, respectively.

Aerobic plate counts (APC) of heat-set products in AIR increased rapidly, reaching spoilage (~10^7 CFU/g) by the 12th day. Heat-set products under MAP showed APC growth rapid after day 6, reaching near spoilage by day 12. However, all precooked products did not show an increase in PPC over the 12 days of storage.

Psychrotrophic plate counts of precooked strips in AIR increased ($P \leq 0.05$) by 1 log CFU/g, and those in MAP did not increase for 12 days. Psychrotrophic counts in heat-set strips under AIR increased rapidly, reaching spoilage levels after day 9, while PPC in heat-set strips under MAP were below spoilage levels after 12 days.

There was no increase in the numbers of *S. aureus* on all samples for 12 days, except in heat-set strips under AIR, which increased by 1.5 log CFU/g in the last 6 days. *S. aureus* did not grow in heat-set products under MAP and seemed to decrease in all precooked products. After reheating heat-set and precooked products, there was absence of any microorganisms, including *S. aureus*. This ensures the safety of these products if *S. aureus* does not grow in sufficient quantities to produce a highly heat-stable toxin. Thus, control of your process to minimize presence and growth of *S. aureus* through the correct implementation of GMPs (21CFR110), SSOPs (21CFR123), and low processing/batter temperatures (21CFR123) is the best preventive measure.

Shelf Life of Channel Catfish Fillets Packed Under a Master-Pack System

Bussakorn Wannappee, Chakrapong Handumrongkul, and Juan L. Silva

Channel catfish fillets processed in the summer of 1996 were packed into PVDC-wrapped trays (AIR), vacuum packed in barrier bags (VAC), or PVDC-wrapped trays placed (six per bag) in a barrier Master bag and backflushed with 90% CO_2, 8% N_2, and 2% O_2 (MAP). Both the VAC and MAP products were placed in barrier bags. All products were held at 36°F (2°C) for up to 28 days. The MAP bags were opened after 16, 20, 24 and 28 days at 36 °F and placed at 45°F (8°C) as AIR packs for up to 6 days.

Products under MAP held at 36°F had initial psychrotrophic counts (PPC) of 4.2 log CFU/g, and reached 7 log CFU/g (spoilage threshold level) after 20-24 days (Figure 1). Most of the psychrotrophic growth under low-oxygen storage was attributed to lactic acid bacteria (LAC) growth, which grew from 1 to over 4 log GCU/g by day 24. Odor (spoilage) and appearance (sliminess) (Figure 2) scores were above the minimum acceptable number by day 24 of storage at 36°F. Sensory spoilage in these products was not reached until day 28, when the PPC levels were above 8 log CFU/g. Thus, one can say that spoilage of catfish fillets under MAP is not reached until PPC levels are 8 log CFU/g, 1 log above reported levels for conventional packed fillets. At this point, lactic acid bacteria levels (LAC) are over 4 log CFU/g, thus the distinctive sour note of the fish as noted by the panelists. In conventionally packed fillets (AIR), spoilage is typical of proteolytic bacteria and thus is more putrid.

Fillets held under AIR or VAC had similar initial counts as those above but reached 7 log CFU/g (microbiological spoilage) after about 5 days at 36°F. At this point, fillets were also rated spoiled by sensory panelists.

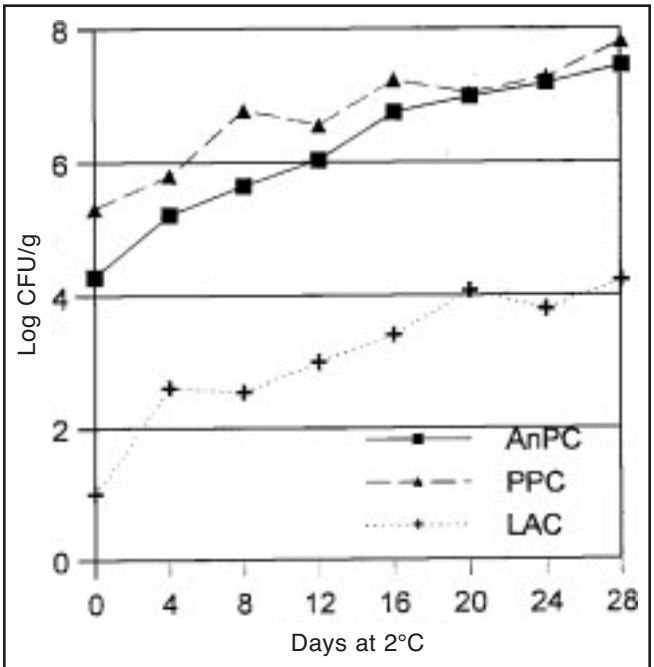


Figure 1. Effect of MAP (master bag) on microbiological evaluations in channel catfish fillets during storage at 2°C (AnPC – Facultative anaerobic plate counts, PPC – Psychrotrophic plate counts, and LAC – Lactobacilli counts).

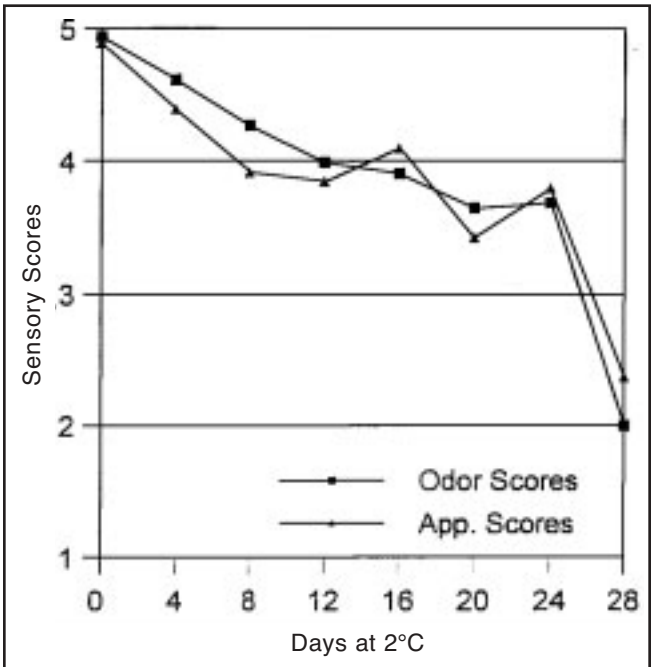


Figure 1. Effect of MAP (master bag) on sensory analysis in channel catfish fillets during storage at 2°C. (Odor: 5 = very fresh, sweet; 3 = slightly spoiled; and 1 = totally spoiled, putrid. Appearance: 5 = very fresh; 3 = slightly slimy; and 1 = completely slimy

Variations in Microbial Contamination Through the Process in Three Typical Catfish Operations

Atilano L. Nuñez, Juan L. Silva, Anna F. Hood, and Roberto S. Chamul

Catfish product, contact equipment, and personnel utensils, from the receiving point to the packaging end (Figure 1), were swabbed and/or collected from three different catfish processing schemes during the fall, winter, and spring (Table 1). Altogether, 495 samples were collected. They were examined for bacterial load variation: aerobic or total (APC), psychrotrophic or cold-loving (PPC), and total coliforms (TCC) plate counts. The APC (Figure 2), PPC (Figure 3), and TCC (Figure 4) load varied depending on processing scheme and season. Processes where live fish are held in tanks (holding vats) prior to stunning showed higher APC and PPC in the finished product (fillets), when compared with product taken directly to stunning. This increased load (~1 log CFU/cm^2) was carried over to the finished product. The processing point with the highest bacterial load was the evisceration place (≥ 7 log CFU/cm^2), whereas the point with the lowest bacterial load was the skinned/dressed fish (~2.63 log CFU/cm^2). Fish processed in the winter had lower counts on the skin, and this was carried throughout (Figures 5, 6). Fillets processed in the spring averaged about 0.8 log CFU/cm^2 higher than those processed in the fall or winter.

Table 1. Sampling point description for a typical catfish process operation.

Point	Fish point	Description
1		Holding tank
2	A	Stunned catfish skin
3		Deheader machine
4	B	Deheaded fish
5		Evisceration site
6		Globes evisceration operator
7	C	Fish skin after evisceration
8		Shank fillet skinner
9	D	Fillet (skin side) after skinner
10		Conveyor belt to chiller
11		Chiller water
12	E	Fish (skin side) after chilling
13		Conveyor to sorter
14		Sorter operator globes
15		Trimming table
16		Globes trimming operator
17		Knives trimming operator
18	F	Trimmed fillet (skin side)
19	G	Frozen fillets (skin side)
20	H	Ice-chilled fillets (skin side)

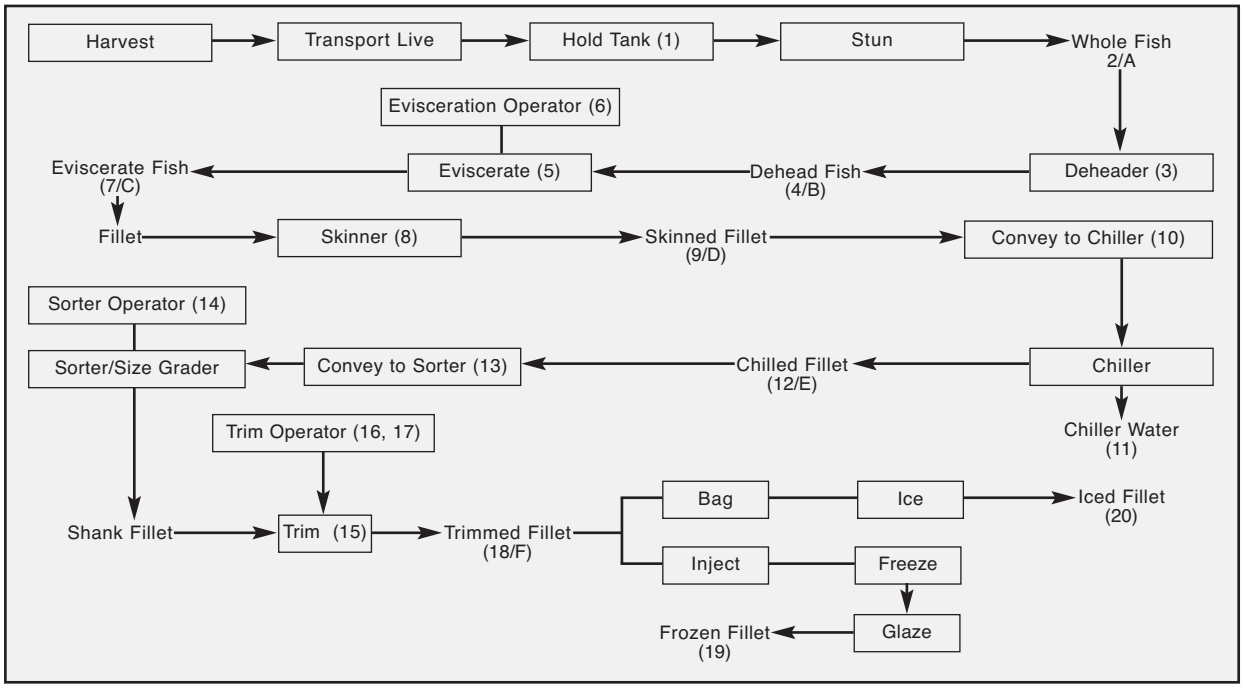


Figure 1. Flow diagram for a typical channel catfish processing operation. (Sampling points indicated in parentheses.)

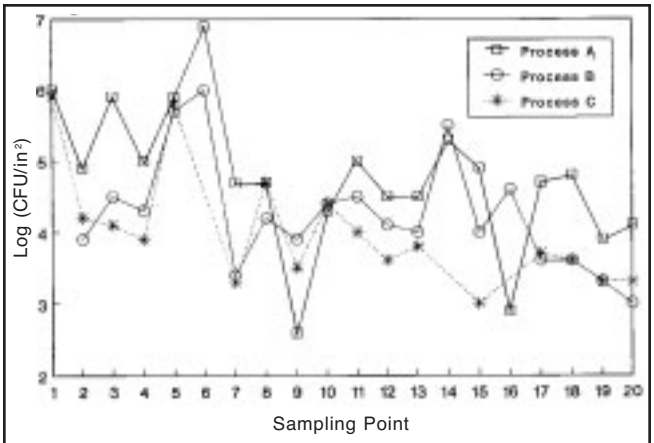


Figure 2. Aerobic plate counts at various points in three different catfish processing schemes.

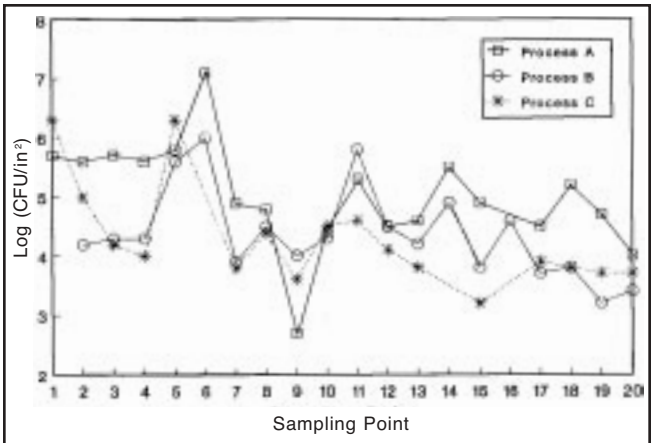


Figure 3. Psychrotrophic plate counts at various points in three different catfish processing schemes.

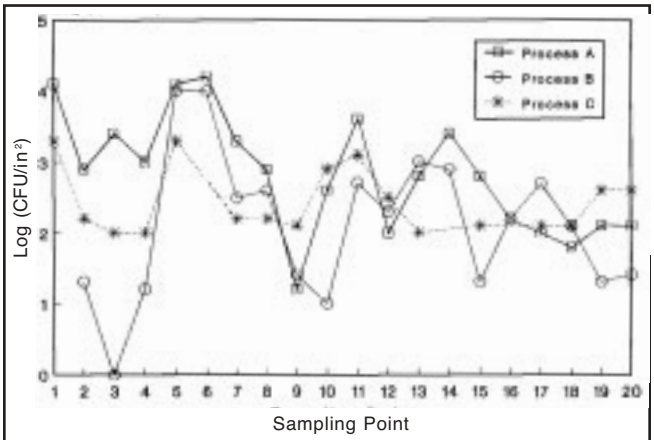


Figure 4. Total coliform counts in three different catfish processing schemes.

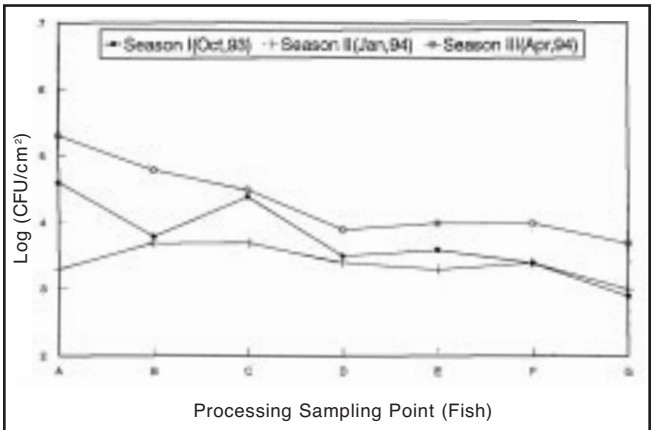


Figure 5. Seasonal variation in aerobic bacterial load of channel catfish in three plants.

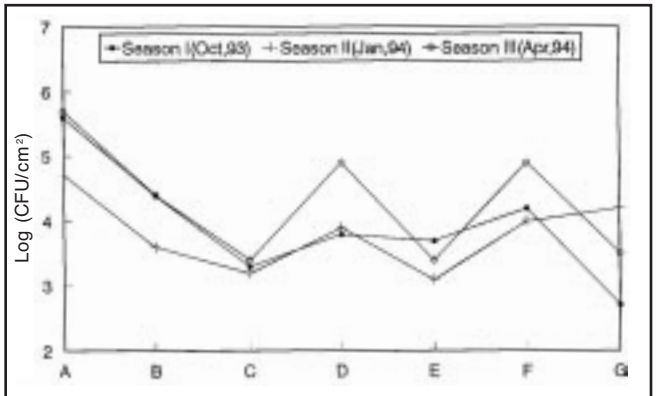


Figure 6. Seasonal variation in psychrotrophic bacterial load of channel catfish in three plants.

Effect of Cleaning/Sanitizing Type on Microbial Loads in a Catfish Filleting Operation

Juan L. Silva, Custy F. Fernandes, George J. Flick, Jr., Thomas A. McCaskey, Estuardo Marroquin, Chakrapong Handumrongkul, and Anna F. Hood

Cleaning and sanitation programs are designed to reduce, prevent, and/or control contamination/cross-contamination of food products in a process environment. These programs are an integral part of the Good Manufacturing Practices (GMPs) (21 CFR 110) and of the new HACCP systems mandated in seafood plants (21 CFR 123) under the Sanitation Standard Operating Procedures (SSOPs) (21 CFR 123). This process has the added feature of enhancing shelf life of the product and assuring the outcome of a safe product. The type of cleaning and sanitation program may also influence the microbial load and profile of the product.

Two parallel automatic filleting lines, from a B166 (BAADER Corp.) deheader to the trimming line, were treated. One was treated using conventional (CON) cleaning (detergent) and sanitation (100 ppm Cl) procedures and the other with a foam (EXP) cleaner (4% chlorinated alkaline detergent) and sanitizer (5% alkyl dimethyl ammonium chloride) using a high-pressure foamer. Utensils, including trimming board and knives, were cleaned and sanitized with 200 ppm Cl (CON) or 2% chlorinated alkaline detergent (EXP). Twenty sampling points in each line were taken during the study.

Aerobic (APC) and total coliform (TCC) counts on deheader (B166) knife, filleter (B184) knife, and skinner (B66) roller area during a 6-hour operation are shown in Figures 1 (APC) and 2 (TCC). All machinery was sampled prior to operation (pre-op) with APC of about 10 CFU/cm^2 and TCC of less than 10 CFU/cm^2. After 1 hour of operation, the EXP-cleaned equipment had higher APC than their CON-cleaned counterparts. This was in part due to difficulty in accessing certain machinery

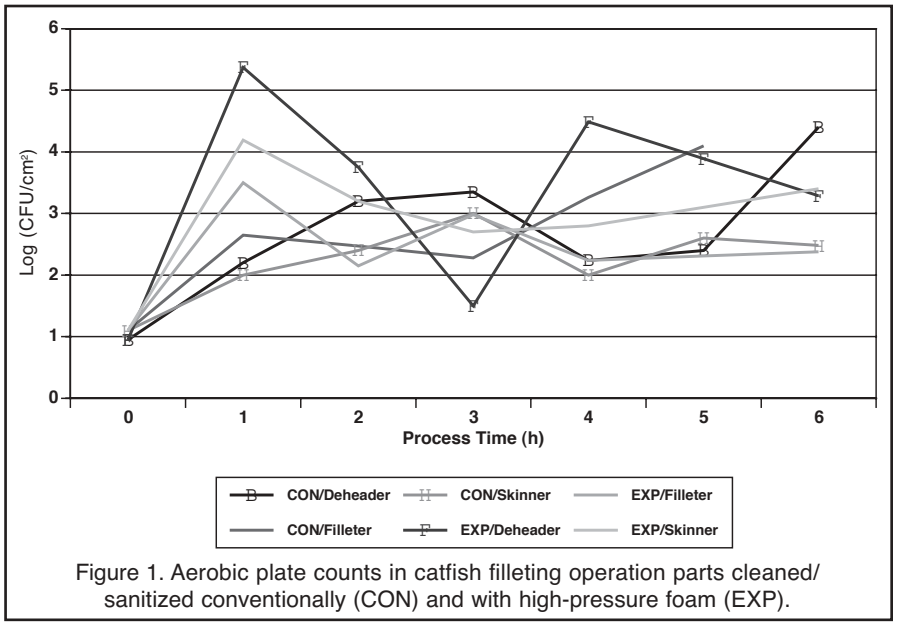


Figure 1. Aerobic plate counts in catfish filleting operation parts cleaned/sanitized conventionally (CON) and with high-pressure foam (EXP).

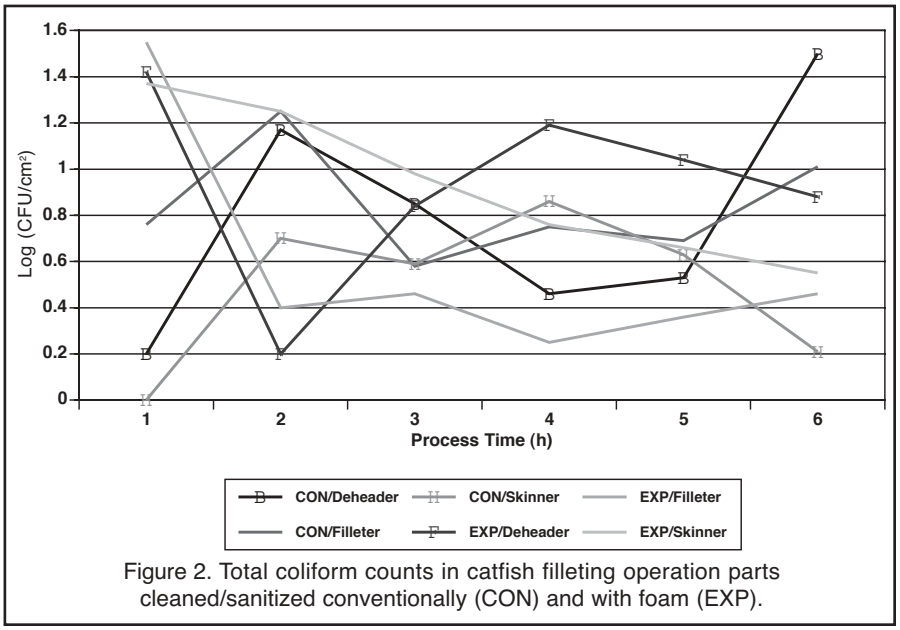


Figure 2. Total coliform counts in catfish filleting operation parts cleaned/sanitized conventionally (CON) and with foam (EXP).

parts by the foam cleaner. This was overcome by the third hour (break time), when additional hand scrubbing and sanitizing were done at the EXP line. However, it was found to be difficult to do adequate cleaning and sanitation during the break, since it was short. Maintenance is also done at this time, adding to cross-contamination, and counts rise almost immediately after cleaning/sanitizing when the processing starts.

A rising trend in APC was noted for the CON-cleaned deheader and skinner roller (Figure 1), but for the most part, APC remained between 2 and 4 log CFU/cm^2 after the first hour of operation. Thus, sampling machinery for APC throughout operation should lead to "hot spots" when APC is over 4 log CFU/cm^2. Cleaning during the break (~2.5 hours after operation) did not change APC much, but it may be a good procedure. However, the type of cleaning/sanitation used did not make a difference.

Aerobic counts (APC) on trimmer utensils (Figure 3) were less than 25 CFU/cm^2 at the start. The conventionally (CON) sanitized utensils have higher counts (>1 log CFU/cm^2) than the foam-sanitized (EXP) utensils (<1 log CFU/cm^2). However, after 1 hour of operation, all utensils show counts between 3.3-4.7 log CFU/cm^2, except for the EXP apron. After 3 hours (break), APC on foam-cleaned apron and gloves decreased due to the cleaning at that moment. No reductions in APC were found on the other utensils. APC remained steady (2-4 log CFU/cm^2) for the remainder of the operation.

Initial APC on catfish products (Figure 4) were about 2.5-4.5 log CFU/cm^2 and remained the same throughout the operation. Thus, type of cleaning/sanitation has little effect on total microbial load of catfish products. Nonetheless, it is necessary to adhere to standard sanitation operating procedures (SSOPs) since these may influence safety (presence of pathogens) of the products.

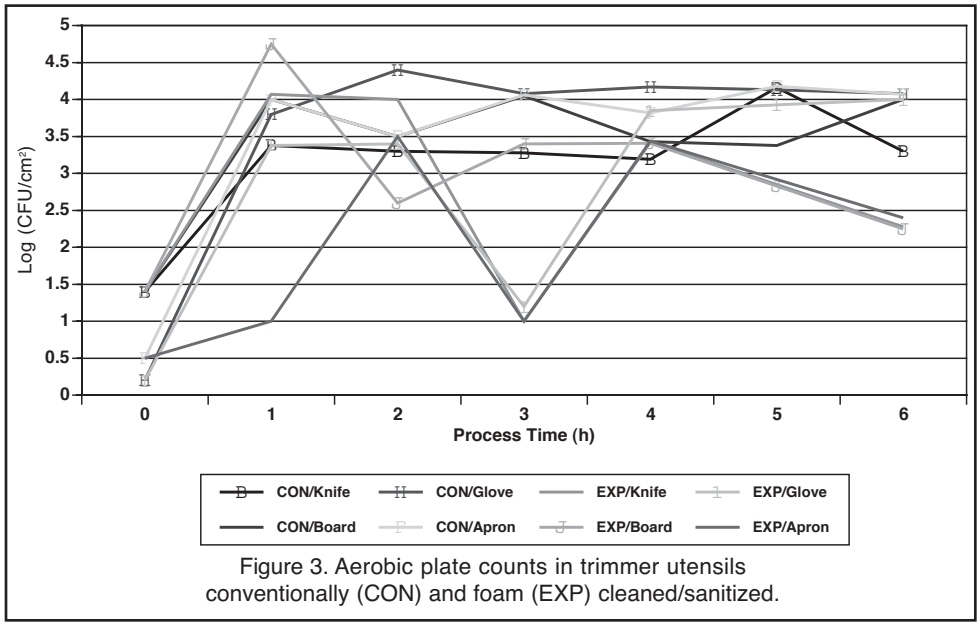


Figure 3. Aerobic plate counts in trimmer utensils conventionally (CON) and foam (EXP) cleaned/sanitized.

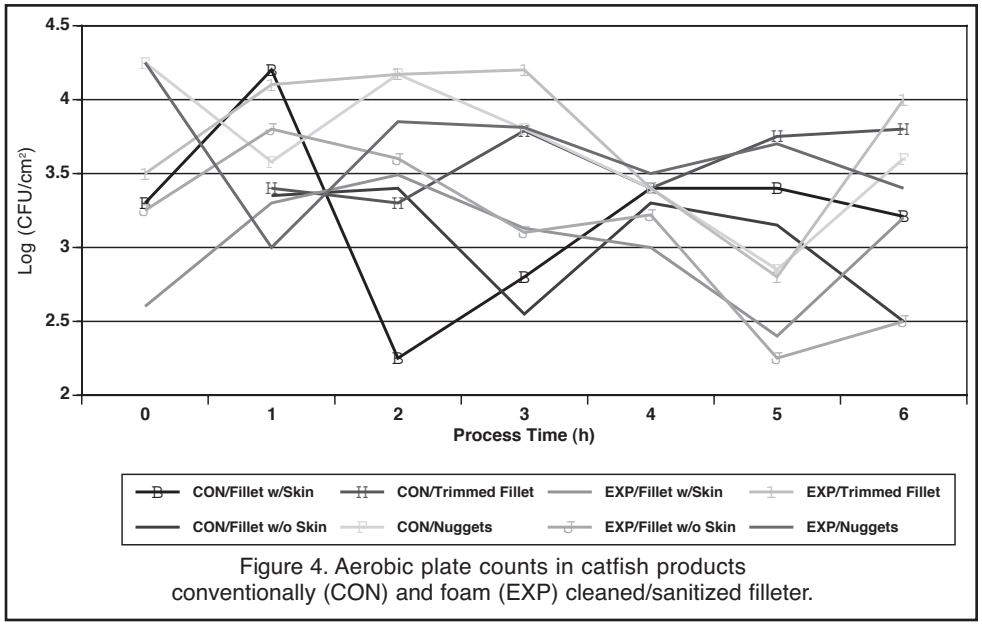


Figure 4. Aerobic plate counts in catfish products conventionally (CON) and foam (EXP) cleaned/sanitized filleter.

Clostridium botulinum **in Modified-Atmosphere Packaged Channel Catfish Fillets**

P. Cai, Mark A. Harrison, Y.-W. Huang, and Juan L. Silva

Channel catfish were inoculated with $\log_{10}$3-4 spores/g of a mixed pool of four strains of *Clostridium botulinum* type E (Beluga, Minnesota, G_{21}-5 and 070) and were packaged with an oxygen-permeable overwrap (Overwrap), oxygen-barrier bag with a modified atmosphere of CO_2:N_2 (80:20) (MAP), or in a master bag with the same modified atmosphere (Master bag). Packaged fish were stored at either 4°C (40°F) and sampled at intervals over 30 days or at 10°C (50°F) and sampled at intervals over 12 days. An additional master bag treatment in which overwrap-packaged catfish was stored first at 4°C for 6 days, then removed from the master bags and stored at 10°C, was sampled at intervals over 18 days. Toxin production was evaluated using the mouse bioassay. Aerobic, psychrotrophic, and anaerobic populations were enumerated and spoilage characteristics were noted.

Under abusive storage conditions of 10°C (Table 1), there was no significant difference among the potential for toxin production in the packaged fish, with *C. botulinum* toxin detected on fish from each package type of day 6. Under 4°C (Table 2), toxin production was detected on day 9 in the overwrapped packages, while it was on day 18 in the MAP. No toxin was found in the master bags. For the variation of master bag (Table 3), toxin was detected on day 18.

Sensory rejection preceded toxin production for all samples in this study. This shows that channel catfish fillets packaged under MAP, to increase shelf life, are safe if produced, packaged, and handled properly. Even under exposure to higher temperatures of storage, the fillets under MAP do not develop toxin before spoilage. Thus, the consumer will reject the fillets before they become toxic.

Table 1. Presence of **C. botulinum** type E neurotoxin in the overwrapped, modified-atmosphere, and master-bag packaged channel catfish held at 10°C.[1]

Days	Overwrap		MAP		Master bag	
	Ctrl.	Ino.	Ctrl.	Ino.	Ctrl.	Ino.
0	ND[2]	ND	0/3[3]	0/3	ND	ND
2	ND	ND	ND	ND	ND	ND
4	0/3	2/3	0/3	1/3	0/3	0/3
6	0/3	3/3	0/3	2/3	0/3	1/3
9	0/3	2/3	0/3	3/3	0/3	3/3

[1]Fillets were either inoculated with C. botulinum spores or were uninoculated (control).
[2]ND = Samples not done.
[3]Number of toxic samples/number of samples tested.

Table 2. Presence of **C. botulinum** type E neurotoxin in the overwrapped, modified-atmosphere, and master-bag channel catfish held at 4°C.[1]

Days	Overwrap		MAP		Master bag	
	Ctrl.	Ino.	Ctrl.	Ino.	Ctrl.	Ino.
0	ND[2]	ND	ND	ND	0/3[3]	0/3
3	ND	ND	ND	ND	ND	ND
6	0/3	0/3	0/3	0/3	0/3	0/3
9	0/3	1/3	0/3	0/3	0/3	0/3
12	0/3	1/3	0/3	0/3	0/3	0/3
15	0/3	0/3	0/3	0/3	0/3	0/3
18	0/3	0/3	0/3	0/3	0/3	1/3
30	0/3	0/3	0/3	0/3	0/3	0/3

[1]Fillets were either inoculated with C. botulinum spores or were uninoculated (control).
[2]ND = Samples not done.
[3]Number of toxic samples/number of samples tested.

Table 3. Presence of **C. botulinum** type E toxin on channel catfish fillets stored in a master bag (CO_2:N_2, 80:20) held at 4°C for 6 days, and then held under air-permeable film wrap at 10°C for 12 days.[1]

Days	Master bag (4°C)		Air-permeable film (10°C)	
	Ctrl.	Ino.	Ctrl.	Ino.
0	0/3[2]	0/3	C	C
6	ND[3]	ND	C	C
8	C	C	ND	ND
10	C	C	ND	ND
12	C	C	0/3	0/3
15	C	C	C	C
18	C	C	0/3	3/3

[1]Fillets were either inoculated with C. botulinum spores or were uninoculated (control).
[2]Number of toxic samples/number of samples tested.
[3]ND = Samples not done.

Reduction of Microbial Loads in Channel Catfish Processing Operations by Use of High-Pressure Sprays and Various Additives

Pedro L. Silva, Juan L. Silva, Chinling Wang, and Mary L. Scruggs

Whole channel catfish (deheaded and eviscerated, skin on) were dipped in water (control) or in 1% and 2% lactic acid or sodium percarbonate (Pergenox®) for 1 and 5 minutes. Whole fish and fillets were also dipped in water (chilled) and high-pressure (80 psig) spray washed for 30 seconds with water or 8% sodium tripolyphosphate (STPP). Impedance detection times (IDT) were recorded for rinsates of the products at different time intervals. Higher IDT indicate lower microbial loads.

Whole fish dipped in water at 20°C had lower IDT (thus higher microbial counts) than treated fish. Fish dipped in 2% lactic acid for 1 or 5 minutes had higher initial IDT than those dipped in 1% lactic acid. Regardless of lactic acid concentration, IDTs were the same in products held more than 1 day at 4°C. Similar results were achieved for products dipped in Pergenox®. Fillets spray-washed in STPP had higher IDTs than the control or spray-washed with water, and the difference was more pronounced after six days at 4°C. For whole fish, STPP had a very significant initial reduction in microbial counts (higher IDT), but the effect was minimal on the product held for 6 days at 4°C.

Thus, rinsing or dipping channel catfish prior to skinning and chilling in solutions of 2% lactic acid, 2% Pergenox®, or 8% STPP would lower microbial loads in the chiller and possibly in the final product. Exposing the product to high-pressure spray wash for a short time did not have a significant effect on IDT, but the addition of STPP in the water did increase IDT and thus lower microbial contamination in whole fish and fillets. This process not only will lower microbial loads in fish products (extend shelf life), but it could possibly decrease the incidence of pathogens in final product if used prior to entering the dressing area.

EXHIBITORS

BLENDO, INC., Brenda Northam; P.O. Box 32, Hattiesburg, MS 39401; Telephone — (601) 544-9800; Fax — (601) 544-5634. (Marinades and breading systems)

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GEM BIOMEDICAL, INC., Patrick Harewood; 925 Sherman Avenue, Hamden, CT 06514; Telephone — (203) 248-4008; Fax — (203) 288-2621. (Rapid microbial test kits)

KALSEC, INC., Tom Jones; 3713 West Main Street, Kalamazoo, MI 49006; Telephone — (616) 349-9711; Fax — (616) 382-3060. (Spice and herb systems, marinades, antioxidants)

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