A PROCEDURE FOR PROCESSING SMOKED CHANNEL CATFISH (*ICTALURUS PUNCTATUS*)

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(Received for publication April 9, 1973)

Abstract

A study was made to determine the most acceptable procedure to prepare smoked channel catfish Effects of storage time before brining, fish weight, brining times and formulae, smoking times and temperatures, and storage time after processing on final product quality were evaluated. Use of freshly dressed catfish yielded a smoked product indistinguishable from that prepared from frozen catfish. Catfish averaging 10.5 oz (dressed) and brined for 24 hr at 40 F in a mixture prepared by dissolving 9 lb sugar (sucrose), 9 lb sodium chloride, 0.23 oz potassium nitrate, and 0.23 oz sodium nitrite in 72 lb water were highly acceptable. A gradual increase of internal flesh temperature from 90 to 140 F over a 22-hr smoking period, followed by an increase to 180 F over 4 hr with an additional 30 min at 180 F was judged as optimal for producing smoked catfish. Sensory panel evaluations on the finished product showed that smoked catfish were equally acceptable when compared with smoked haddock and chubs.

Production of farm-grown channel catfish in southeastern United States exceeds 50 million lb per year. Approximately half is sold as a frozen product while the remainder is sold as fresh processed catfish. To the authors' knowledge, none has been commercially sold as a smoked product.

Salmon, chub, herring, haddock, sablefish, mullet, and sturgeon are fish species generally smoked in the U. S. and are most common in the Pacific Northwest and Great Lakes area. Federal regulations assuring quality control have been established for processing and distribution of these smoked fishes (5). If smoked and handled properly, the product is considered a delicacy and, it might be added, as a luxury when considering its retail price.

With these points in mind, experiments were designed to develop a suitable processing procedure for preparing smoked channel catfish.

Experimental Procedure

Brining and curing procedures

Several preliminary experiments were done before arriving at the most acceptable brining formula, temperature and time of brining, and catfish size for producing the smoked channel catfish (*Ictalurus punctatus*). In addition, methods of killing and storage of the catfish before brining and smoking were evaluated. Those experiments contributing valuable data which were utilized in formulating the final recommended procedure are listed:

Experiment 1. Skinned and unskinned frozen catfish were thawed at room temperature, weighed, and submerged 17.5 hr at 50 F in a brine suggested by Tiemeier (8) which consisted of 2.0 lb light brown sugar and 1.5 lb salt (NaCl) in 16.5 lb water. The ratio of brine to fish was 3:2 (w/w).

Experiment 2. Frozen skinned and unskinned catfish were thawed at room temperature and weighed. Fish were then rubbed at a rate of 3/4 oz per pound of fish with a salt mix prepared by combining 1 lb salt, 4 oz sugar (sucrose), 0.12 oz potassium nitrate (KNO_3), and 0.12 oz sodium nitrite ($NaNO_2$). After 24 hr at 50 F the procedure was repeated, thus resulting in a total salt application of 1.5 oz/lb of catfish; 24 hr after the second rub fish were turned. Excess salt was rinsed from the fish with warm tap water after an additional 24 hr (3 days total salting). The fish were then weighed and smoked.

Experiment 3. Catfish examined in this experiment had been subjected to various killing procedures and to various conditions between death and brining. Treatments and conditions were: *(a)* death by electrical stunning, dressed, and brined (control); *(b)* death by suffocation, held in the round 12 hr at 32 F, dressed, and brined; *(c)* death by suffocation, dressed, held 3 months at 0 F, thawed at room temperature, and brined; *(d)* death by suffocation, held in the round 12 hr at 32 F, dressed, held 3 mo at 0 F, thawed at room temperature, and brined; and *(e)* death by electrical stunning, dressed, held 30 months at −40 F, thawed at room temperature, and brined. All catfish in these experiments were skinned. Brine was prepared by dissolving 3.0 lb sugar, 4.5 lb salt, 0.56 oz KNO_3, 0.56 oz $NaNO_2$ and 0.21 oz sodium ascorbate in 24.9 lb water. All catfish were weighed and submerged (with occasional agitation) in an equal weight of brine for 17.5 hr at 50 F before smoking.

Experiment 4. An investigation was made of the effect of brining time and fish size on quality of the finished smoked product was made. The brine formula, consisting of 2 lb sugar, 2 lb salt, and 0.12 oz potassium nitrite (KNO_2) in 16 lb water, was employed at a 1:1 (w/w) ratio with the catfish. Skinned fish had been frozen 3 months and thawed at room temperature. Brining times at 40 F were 4, 8, 16, and 24 hr. Two lots of catfish averaging 8.75 and 12.25 oz each were evaluated at each brining time.

Experiment 5. The effect of a wider range of catfish weight on finished product quality was further studied. Three lots of frozen, skinned catfish averaging approximately 7, 10.5, and 14 oz were thawed at room temperature. Fish were submerged at 40 F for 24 hr in an equal weight of brine formulated by dissolving 9 lb sugar, 9 lb salt, 0.23 oz KNO_3 and 0.23 oz $NaNO_2$ in 72 lb water. Fish were agitated occasionally during brining. Catfish were weighed before and after brining.

Smoking procedures

Temperatures and times of smoke-curing were varied to optimize smoking conditions with those of brining, thus re-

sulting in the most desirable product. Smoke was generated by using moist hickory wood chips in a thermostatically controlled smokehouse manufactured by Griffith Laboratories (Chicago, Illinois). Catfish temperatures referred to below are internal loin temperatures and were measured by inserting thermometers into the thickest portion of the loin muscle. Experiment numbers listed below for smoking correspond to brining experiments.

Experiments 1 and 2. Catfish were suspended by the tail from metal rods and placed in the smoking chamber at 120 F for 20 hr after which half of the skinned and unskinned fish were removed. The temperature of the chamber was then gradually increased to 205 F over a 2.5-hr period, bringing the temperature of the remaining catfish to 175 F.

Experiment 3. Catfish were placed in the smoking chamber at 90 F for 5 hr during which their internal temperature increased to 75 F. Chamber temperature was then maintained at 120 F for 7 hr resulting in a catfish temperature of 110 F. Finally the chamber temperature was brought to 195 F over a 2-hr period to bring the fish temperature to 175 F. Fish were removed after an additional 30 min.

Experiment 4. Catfish from various brining times were hung in the smoking chamber adjusted to 100 F. The chamber temperature was gradually increased to 200 F over a 7-hr period, resulting in a fish temperature of 175 F. Fish were removed after 30 min at 175 F.

Experiment 5. Three lots of catfish representing different weight groups were placed in the smoking chamber at 115 F. The internal flesh temperature gradually increased to 90 F during the first 3 hr; a gradual increase in chamber temperature to 170 F over the next 19 hr resulted in a flesh temperature of 140 F. The chamber was then increased to 192 F during the next 3 hr of smoking and maintained at this temperature for an additional 1.5 hr. Internal fish temperature increased from 140 F to 180 F in 4 hr during the time the chamber tempereture was increased to 192 F and remained at 180 F for 30 min before removal.

After smoking as outlined in Experiments 1 through 4, catfish were removed from the smoking chamber, packaged in polyethylene bags under atmospheric conditions, and held at 37 F until further evaluation. Smoked catfish from Experiment 5 were air-cooled at 37 F before packaging.

Analytical methods

Five-gram portions of homogenized fish fillets were dried at 160 F in a vacuum oven for 24 hr and the moisture content was determined by difference.

Fat determination was according to a method by Young *(11)*. The method consisted of drying 5-g samples of homogenized fish for 5 hr at 230 F, suspending the dried flesh in 10 ml diethyl ether overnight, removing 5 ml of clarified ether containing dissolved fat, evaporating the ether in a tared vessel, weighing, and calculating the percent fat originally contained in the flesh.

Methods outlined in the USDA *Chemistry Laboratory Guidebook (9)* were followed to determine the nitrite and NaCl contents of smoked fish.

Total aerobic plate counts were made from swabs of 10-cm^2 areas of the anterio-dorsal region of the fish. Appropriate dilutions of each swab were made in sterile 0.1% peptone and the organisms were recovered on Standard Methods agar (BBL) using the pour-plate technique. Incubation was at 21 C (69 F) and counts were made after 4 days.

Sensory evaluation

During preliminary tests to determine the most satisfactory brining and smoking conditions (Experiments 1 through 4), a six-member trained panel was requested to assign scores for appearance, color, aroma, texture, and flavor to the finished product. A 20-member untrained panel was later used to evaluate catfish judged to exhibit the most acceptable quality (Experiment 5). Samples of fish loin muscles were scored for aroma, texture, and flavor in a blind test against smoked chubs and haddock obtained from a local delicatessen. In all instances a nine-point hedonic scale (1 = extremely poor; 9 = excellent) was used. Data were subjected to Duncan's multiple range test *(4)*.

RESULTS AND DISCUSSION

Experiments 1 through 4 were exploratory in nature. Information derived from these experiments served to establish a basis for the recommended brining and smoking procedures included in Experiment 5. Rather than presenting details from Experiments 1 through 4, only those data having significant influence on the final recommended procedure for preparing smoked catfish are discussed.

In *Experiments 1 and 2*, a trained six-member panel judged skinned catfish to be more desirable than unskined catfish for smoking, regardless of whether the fish had been brined or dry-rubbed. Skinned catfish consistently exhibited a more attractive color and rated higher in desirable aroma and flavor characteristics. Skin undoubtedly acted as a barrier to the penetration of brine and curing salts and to smoke, thus resulting in a product with lower aroma and flavor. Upon refrigeration, fat deposits were noted between the skin and loin muscle. Such undersirable deposits apparently accumulated during the smoking process when the skin was separated from the loin muscle due to heat. The 2.5-hr extension in smoking time at higher 175 F resulted in a more desirable flavor and, more importantly, was judged as necessary for adequate pasteurization. Salt-rubbed catfish were generally as acceptable as the brined fish of *Experiment 1*, however, the method was not investigated further because of the increased time required in preparing the fish when compared to brining. Brown sugar was judged to have no advantage over sucrose in flavor development.

Experiment 3 yielded at least three important findings. First regardless of slaughtering conditions and time of storage up to 30 months in the frozen state before brining and smoking, finished products were virtually indistinguishable with respect to appearance, color, aroma, texture, and flavor. Secondly, slight to moderate muddy odor and flavor present in some catfish were observed to disappear or become masked during smoking. Fish judged slightly undesirable because of these qualities might therefore be utilized after smoking. Iredale and Rigby *(6)* have also noted this phenomenon in rainbow trout. A third observation was that both internal and external color were improved through the use of KNO_3 and $NaNO_2$ in

TABLE 1. MEAN SUBJECTIVE SENSORY SCORES FOR SMOKED CATFISH BRINED 4, 8, 16 AND 24 HR

Brining time (hr)	Appearance	Color	Aroma	Texture	Flavor
4	6.97[a]	7.40[a]	7.42[a]	7.37[a]	6.40[a]
8	7.38[b]	7.50[a]	7.72[a]	7.43[a]	6.80[a]
16	7.37[b]	7.50[a]	7.80[a]	7.90[b]	7.43[b]
24	7.40[b]	7.77[a]	7.62[a]	7.90[b]	7.90[b]

[a, b]Values in the same vertical column bearing the same letter are not significantly different ($P < 0.05$).

TABLE 2. MEAN SUBJECTIVE SENSORY SCORES FOR SMOKED FISHES

Fish	Aroma	Texture	Flavor	Average
Catfish	6.80	7.10	6.30	6.73
Haddock	6.25	5.95	7.10	6.43
Chub	6.70	6.20	5.65	6.18

the brine. Internal pink coloration was initially most intense in muscle nearest the back bone but diffused somewhat during storage. The external appearance was bright and was described as mahogany-gold in color.

Statistical analyses of data from *Experiment 4* showed no differences ($P < 0.05$) in appearance, aroma, color, texture, and flavor between the 8.75- and 12.25-oz average groups of smoked catfish. No significant differences were shown in appearance, aroma, color, or texture of catfish representing various size-brine time combinations when panels were conducted 1, 14, and 31 days after processing. There was no significant difference in flavor between catfish stored 14 and 31 days at 37 F, however both extended storage times showed improvement at a statistically significant level over freshly processed smoked catfish.

Results showing the effect of brining time (*Experiment 4*) on the finished product are in Table 1. The fish were evaluated by a trained panel after 14 days storage at 37 F. Appearance did not differ among 8-, 16- ad 24-hr brines but all were statistically different from the 4-hr brined fish. The 4-hr catfish were somewhat dull and less acceptable than those brined longer. Color and aroma were not shown to be different by the statistical analyses employed. Analysis of ratings for texture showed that there were no significant differences between 4- and 8-hr brines nor were there any differences between 16- and 24-hr brines, although the 4- and 8-hr brines differed and were inferior to the 16- and 24-hr brines. The same pattern was established for flavor. Therefore, based on the analyses of appearance, texture, and flavor it was concluded that 16- and 24-hr brines were superior in producing smoked catfish. Since appearance and flavor scores were numerically greater for catfish brined 24 hr, the longer brining time was judged more desirable.

The brine formula and smoking conditions employed in *Experiment 5* were judged as optimal, based on all previous experiments, for producing smoked catfish. Tested in this experiment was the effect of a wider range of fish sizes (weight) on final quality. Catfish in the 7-oz average group were judged as too salty and showed a 37.5% loss in weight caused by processing. The 10.5- and 14-oz groups were rated as having superior flavor and averaged approximately 28% weight loss during processing. The 10.5-oz size is recommended because it is easily handled during smoking. Heavier fish tended to detach from their tails during smoking and fall from the racks and could therefore result in significant economic loss on a commercial basis. Larger catfish should be attached to the rod in the smoking chamber by a hook through the belly flap rather than by the tail.

Smoked catfish, having been produced in accordance with the brining and smoking procedures described in *Experiment 5* were then evaluated by a 20-member untrained panel, 16 of whom had never sampled smoked fish. The panel evaluation was performed after 1 week of storage at 37 F. Portions of loin muscle from haddock and chubs were also

TABLE 3. PROXIMATE ANALYSES OF SMOKED AND RAW FISHES

Fish	Time of brine (hr)	Wt before brine (oz)	Wt loss[a] (%)	Moisture[b] (%)	Fat[b] (%)	NaCl[b] (%)	$NaNO_2$[b] (ppm)	Edible wt[a] (%)
Catfish	0	12.3	—[c]	69.5	12.0	TR[d]	0	—
	24	11.5	23.0	58.2	13.1	2.89	39	77.5
		10.2	27.9	58.8	12.3	3.26	44	79.9
Chub	—	—	—	71.0	9.7	2.85	162	59.0
Haddock	—	—	—	59.2	20.9	2.34	TR	—

[a]Calculations are on a wet weight basis, entire smoked carcass.

[b]Calculations are on a wet weight basis, edible flesh; all analyses were on smoked fish with the exception of catfish with 0 hr brine (raw fish).

[c]No test performed.

[d]Trace

included in the blind panel, the results of which are presented in Table 2. Mean scores are shown for aroma, texture, and flavor while average values reflect overall sensory ratings for each fish. Statistical analyses showed no significant differences at the 95% confidence level for any of the sensory characteristics. This was, in part, due to the wide range in ratings obtained from the 20-member panel. Although each of the fish species tested by the panel have natural differences, they also exhibit similarities. There was no attempt to produce a smoked catfish indistinguishable from other smoked fishes. However, we assumed the haddock and chub to be of excellent quality and are therefore categorizing the catfish as having like quality based on the data obtained. In other words, although scores for all smoked fishes shown in Table 2 are acceptable, they undoubtedly would have been higher had the panel been composed entirely of trained members.

Proximate analyses for 24-hr brine catfish from *Experiment 5*, in addition to data for raw catfish, chubs, and haddock are shown in Table 3. Catfish have several competitive advantages over chubs when smoked. The process yield for catfish is approximately 75% (calculated by difference from weight loss data); a similar figure was given by Bratzler and Robinson *(2)* for processed Great Lakes chubs. An even higher process yield for catfish might be achieved through the use of elevated relative humidities in the smoking chamber. Because the head and skin (in addition to viscera) are removed from catfish before brining and smoking, 78% of the resulting product is edible compared to 58% for chubs (Table 3). In addition to supplying 34% more edible flesh than chubs on a purchase-weight basis, the catfish flesh is extremely easy to remove from the bone structure. Fine bones radiating from the backbone of chubs and sometimes inhibiting complete removal of the loin muscle, present no problem in catfish.

Qualities exhibited by the finished product were dependent on the brining formula, temperature and time, ratio of brine to fish, size of fish, smoking temperatures, time of smoking, and storage time after processing. Many of these factors have been also noted to affect quality of smoked chubs *(10)*. Altering any of the recommended procedures may therefore result in smoked catfish exhibiting different characteristics. A processor may be unable to duplicate the product described here, especially if his smokehouse is designed differently *(1)*. It should be noted that, although smoking chamber temperatures and times are given in various experiments above, the time of smoking at specific internal loin muscle temperatures is most important. Necessary modifications in the process should not be extensive.

Procedures outlined in *Experiment 5* to produce smoked catfish are judged as adequate with regard to quality control. No aerobic bacteria were recovered from the smoked product after 31 days storage at 37 F. Although good manufacturing practices and current FDA regulations stipulate levels of $NaNO_2$ only for smoked chubs *(5)*, the sodium chloride content in the water phase of catfish processed in accordance with procedures described in *Experiment 5* approximates 4.8% when calculated by the following formula:

$$\% \text{ NaCl} = \frac{\text{g NaCl in sample} \times 100}{\text{g NaCl} + \text{g } H_2O \text{ in sample}}$$

This satisfies the minimum water phase NaCl for hot-processed smoked fish which has been set at 3.5%.

Catfish is a popular menu item in Southeastern U.S., but it is usually prepared by deepfat or pan frying or by broiling or baking. Smoked country-cured pork products are also highly acceptable. It should be stressed to those unfamiliar with smoked fish, however, that handling and storage of smoked catfish is considerably different from, say, country-cured ham. It is suggested that regulations set forth in the City of Milwaukee Ordinance for smoked fish and smoked fish products *(3)* established in 1964 and current FDA regulations *(5)* should be applied to smoked catfish processing and distribution. Pace and Krumbiegel *(7)* recently summarized the Milwaukee ordinance: *(a)* smoking shall consist of heating every portion of every fish to a minimum temperature of 180 F (82.2 C) for a minimum of 30 min, *(b)* fish shall be removed from the smoking chamber to a separate room for prompt cooling, and must be packaged within 2 hr after completion of smoking, *(c)* the packages shall bear the words "Perishable—Keep Refrigerated," *(d)* the package shall not be sealed so that exchange of air is prevented, *(e)* the package shall bear the processing date and expiration date, *(f)* every smoked fish shall be maintained at a refrigeration temperature of no more than 40 F (4.5 C) from the time of packaging, during transportation, and during display, and *(g)* the expiration date for smoked fish shall be not more than 7 calendar days following the date of smoking. We recommend that the maximum refrigeration temperature under point *(f)* be reduced to 37 F (2.8 C). Adherance to these regulations should preclude the possibility of growth and toxin production by *Clostridium botulinum* in addition to preserving the organoleptic quality of smoked catfish.

ACKNOWLEDGMENTS

We are grateful to Skidaway Institute of Oceanography, Savannah, Ga. for supplying some of the channel catfish used in this study. Technical assistance from L. Bledsoe, N. Perry,

and B. Vaughn and assistance with statistical analyses from D. Parvin and J. C. Elrod, Agricultural Economics Department, is appreciated.

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FOOD PRESERVATIVES APPEAR SAFE

Two food preservatives that have been under suspicion have come through tests looking beneficial in several respects involving cholesterol and fat digestion. In fact, one preservative may have medical use for lowering high blood cholesterol levels in humans.

The preservatives are BHA and BHT (butylated hydroxyanisole and butylated hydroxytoluene). They are used in many food products to prevent oxidation of fats which can cause stale flavors to develop during storage. Rat studies had suggested that these materials increase cholesterol and change lipid phosphrus levels of the blood. Their continued use as food preservatives was questioned.

University of Wisconsin food scientist A. L. Branen recently conducted research with these materials fed to young monkeys. Monkeys' digestive systems are more comparable to man's than are the digestive systems of rats. He fed both materials in a diet high in corn oil. Corn oil is a fat reputed to give fewer cholesterol problems than other fats. He traced the levels of various lipids (products of fat digestion and production) and cholesterol in the monkeys' blood and livers. The formation of fatty livers is a health problem associated with fat metablism.

Lipid levels changed in all the treatments, Branen found. But the potentially harmful changes seemed due to the corn oil—not to the BHA or BHT. In fact, high levels of BHA (500 mg. per kg.) seem to prevent many of the changes produced by corn oil. BHT prevented some change, but generally not as well as BHA . This agrees with previous findings by other researchers, Branen points out. It may be that the preservatives prevent oxidation of lipids or interfere with lipid production in some way.

Since BHT at a relatively low level (50 mg. per kg. daily) reduced serum cholesterol, it may have medical use for treating patients with high cholesterol levels, Branen states.

Branen also is studying the role of BHA in preventing mold poisoning in foods. Various Aspergillus organisms can produce aflatoxins. This is related to lipid synthesis by the molds. BHA interferes with lipid synthesis. It appears that 250 parts per million of BHA inhibits both growth and toxin production by such molds, so it acts as a mold preventer as well as an antioxidant.