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PRELIMINARY REPORT ON EXPERIMENTAL SMOKING OF CHUB (LEUCICHTHYS SP.)

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ABSTRACT

Owing to the recent problem created by bacterial contamination, the smoked fish industry of the Great Lakes faces the task of producing a marketable product under modified processing conditions. This article reports on the results obtained when chub was experimentally smoked under the processing requirements of the various State and Federal regulatory groups concerned. The results show that for industry to conform with those requirements, substantial changes will be necessary in its traditional processing methods.

INTRODUCTION

The smoked fish industry of the states surrounding the Great Lakes is of considerable cal importance. Production of chub for smoking in 1962 and 1963, for example, was about) to 11 million pounds a year. In late 1963, however, bacterial contamination of smoked chub id whitefish resulted in the overnight collapse of that industry owing to the reactions of con- mers and of regulatory groups.

The U. S. Food and Drug Administration, with the follow-up of several State regulatory gencies, published advisories specifying processing and storage conditions under which the dustry would be permitted to resume production and distribution of smoked fish from the reat Lakes. Those advisories have raised the immediate question as to whether smoked ub processed and stored as specified by the various regulatory agencies would be an ac- ptable product. A preliminary investigation by a Bureau team of researchers showed that e industry lacked the answer to this question and that there was little if any reliable data on rrent processing techniques.

To assist the industry toward an ultimate solution of the botulism problem, the Bureau t up two main lines of research--one dealing with the microbiological aspects of the prob- m; the other with the technological aspects of processing. The microbiological work, which being carried out under contract, will be reported separately. The present article is re- icted to reporting on our preliminary investigation of processing. In presenting these re- lts, the Bureau recognizes that the interim processing regulations of the various regulatory oups and herein evaluated are definitely preliminary. We must await results from the long- -range microbiological studies before a final regulatory code can be evolved.

The general objectives of the present investigation (January 20-February 20, 1964) were mited to the evaluation of process variables associated with the interim minimum require- ents for the heat processing of smoked chub (180° F. for 30 minutes) as set forth by the

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Food and Drug Administration and as interpreted by the various State agencies. The three main objectives in the work being reported here were therefore:

I. To evaluate the heat process (180° F. for 30 minutes) specified in the interim regulations and to supply the technical information necessary to achieve that process.

II. To determine whether smoked chub heat processed as specified would be an acceptable product.

III. To evaluate some of the processing variables and raw-material variables in conjunction with the process specified by the new regulation.

EVALUATION OF INTERIM REGULATION HEAT PROCESS

In general, the smoking and processing practice of the industry is still an art, rather than a technologically controlled process. Most processors lack both the devices necessary to measure internal fish temperatures during smoking and the equipment necessary to control the smoking operation. Accordingly, data were needed for evaluating the feasibility of the process specified by the new regulation.

As the study of experimental smoking progressed, it became apparent that the industry needed information on the following:

1. Smokehouse heat-input requirements.
2. Measurement of internal temperature of chub.
3. Temperature differential between internal fish temperature and smokehouse temperature.
4. Total process time.
5. Smokehouse-temperature uniformity.

SMOKEHOUSE HEAT-INPUT REQUIREMENTS: Smokehouse heat-input requirements were studied to determine the additional input of heat needed to raise the internal fish temperature to the regulation process temperature of 180° F. in a reasonable time (say, 2 to 3 hours).

General Processing Procedure: In all the studies reported in this article, we employed essentially the same equipment, raw materials, and methods. The smokehouse used was a relatively simple, electrically heated smoker designed to smoke meat products in small

Fig. 1 - Hanging brined chub onto sticks.

Fig. 2 - Loading smokehouse.

plants. Owing, however, to the high B. t. u. heating demand for smoking of fish to 180° F. because of short-time process with high-moisture-evaporative load), it was necessary to quadruple the heat input by the addition of a gas burner. To obtain more uniform distribution of heat and smoke, we added baffling within the smoking cabinet, a blower to obtain forced circulation inside the smokehouses, and a second blower to feed the maximum amount of smoke from an external smoke generator into the smokehouse. A multipoint recording potentiometer permitted continuous recording of temperatures. At least 10 thermocouples were employed during each run, generally 4 in the smokehouse and 6 or more embedded in the fish. The material consisted of frozen eviscerated chub. In most instances, the chub were thawed and prepared for brining and smoking in accordance with industry practice, and smoking and heat processing were carried on simultaneously. The control of humidity was not practical at the experimental temperatures used. (Note: Most of the industry smokehouses do not now employ humidity control.)

Product load and heat input were the variables in these preliminary experiments.

Findings: A large heat input far exceeding that generally available in Great Lakes commercial smokehouses is required to bring the internal fish temperature to 180° F. in 2-3 hours. A comparison of figures 3 and 4 shows the effect of increasing the heat input by 4 to 5 times for a fixed product load. The rapid heating shown in figure 2 was necessary to ensure an acceptable yield and to avoid overdrying the product.

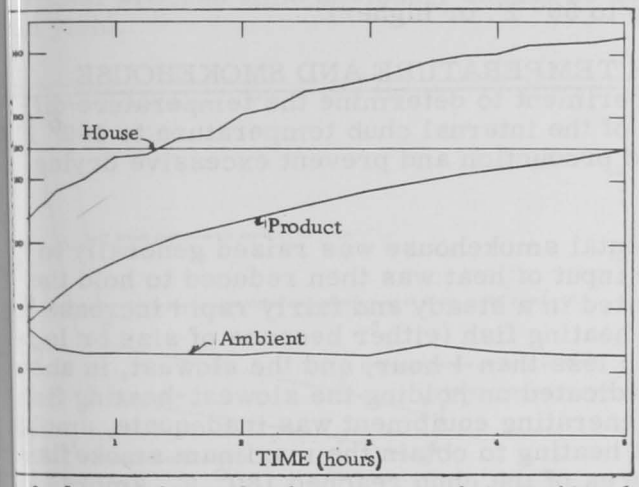

Fig. 3 - Increase of internal product temperature during smoking of chub. (Heat input: 350 B.t.u./cu. ft. hr.; product load: 50 lbs.)

In determining heating requirements, the processor must also take into account the product load. In figure 5, where the product load is approximately four times that in figure 4, the process is significantly lengthened.

TEMPERATURE MEASUREMENT: Temperature measurement was studied to determine the most reliable method for measuring the internal temperatures of chub during smoking.

Procedure: Initially, we measured internal fish temperatures by a thermocouple

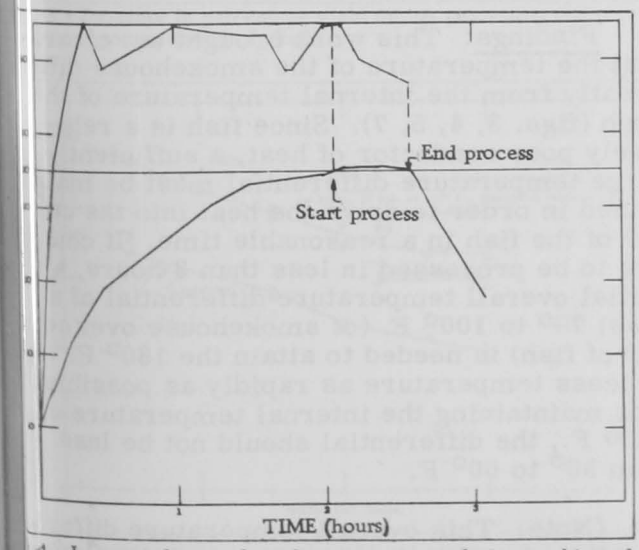

Fig. 4 - Increase of internal product temperature during smoking of chub. (Heat input: 1,600 B.t.u./cu. ft. hr.; product load: 50 lbs.)

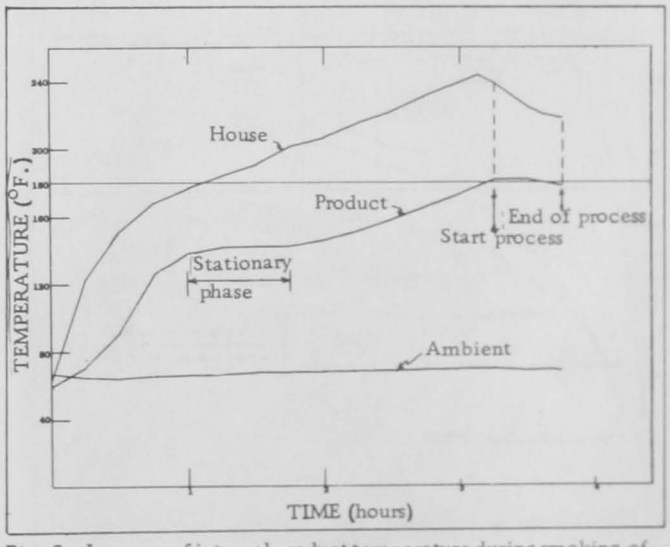

Fig. 5 - Increase of internal product temperature during smoking of chub. (Heat input: 1,300 B.t.u./cu.ft. hr.; product load: 220 lbs.)

inserted along the axial length of the fish in its thickest part (midway between its outer and inner surface). Experience demonstrated, however, that we obtained more accurate temperatures by bending the thermocouple (90 degrees) about one-half inch from its end (depending on the size of the fish), and inserting the thermocouple wire at right angles to the chub surface near the dorsal fin in the thickest part of the fish, securing the thermocouple wire to the fish by wrapping a few turns of string or preferably thin wire around both the fish and the thermocouple wire.

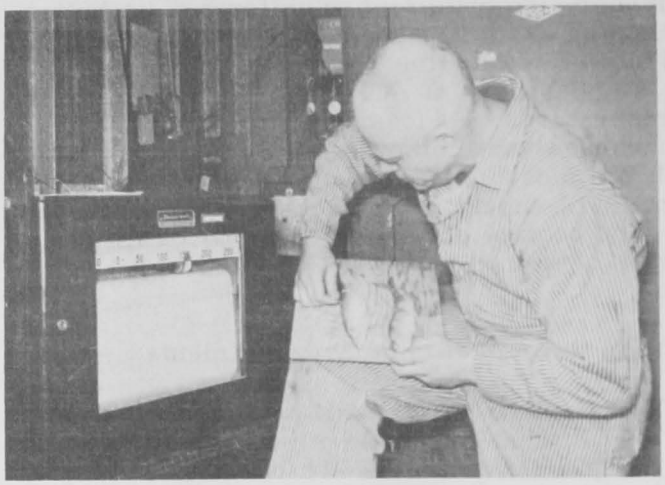

Fig. 6 - Securing thermocouple wire to chub.

Findings: Special "point-sensitive" temperature-measuring devices properly secured are necessary to give true internal fish temperatures, especially for small fish such as chub. The use of large temperature-sensitive bulbs give readings that differ markedly from the true internal fish temperatures (possibly up to 50° F. or higher).

DIFFERENTIAL BETWEEN INTERNAL FISH TEMPERATURE AND SMOKEHOUSE TEMPERATURE: We conducted the following experiment to determine the temperature differential needed to obtain a rapid continuous rise of the internal chub temperature to 180° F. Rapid temperature rise is important both to speed production and prevent excessive drying of the product.

Procedure: The temperature in the experimental smokehouse was raised generally to 240° to 250° F. in about 15 to 30 minutes, and the input of heat was then reduced to hold the temperature within that range. This method resulted in a steady and fairly rapid increase in the internal temperature of the fish. The fastest-heating fish (either because of size or location in the smokehouse) usually reached 180° F. in less than 1 hour, and the slowest, in about $1\frac{3}{4}$ hours, making the total run about $2\frac{1}{4}$ hours (predicated on holding the slowest-heating fish at 180° F. for 30 minutes). Because the smoke-generating equipment was inadequate, smoking usually was continued through the entire period of heating to obtain the maximum smoke flavor and desirable color. When the internal temperatures of the chub reached 180° F., smokehouse temperatures were slowly lowered to determine at what temperature differential the internal temperature of the fish begins to fall.

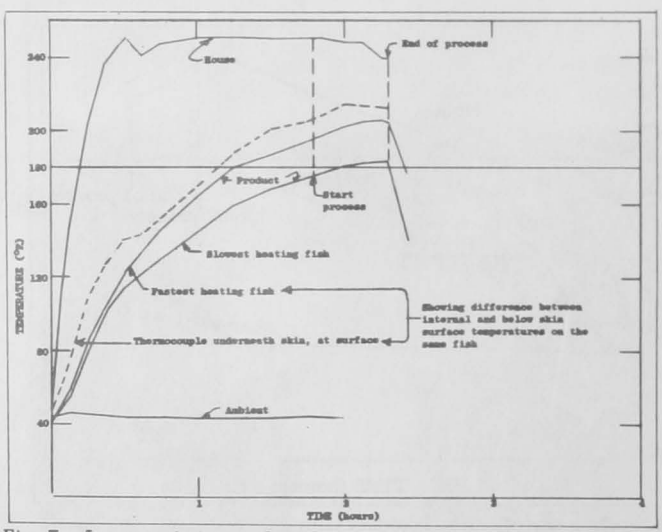

Fig. 7 - Increase in internal product temperature during smoking of chub. (Heat input: 1,600 B.t.u./cu.ft.hr.; product load: 40 lbs.)

Findings: This work brought out clearly that the temperature of the smokehouse differs greatly from the internal temperature of the chub (figs. 3, 4, 5, 7). Since fish is a relatively poor conductor of heat, a sufficiently large temperature differential must be maintained in order to drive the heat into the center of the fish in a reasonable time. If chubs are to be processed in less than 3 hours, an initial overall temperature differential of at least 70° to 100° F. (of smokehouse over center of fish) is needed to attain the 180° F. process temperature as rapidly as possible. For maintaining the internal temperature of 180° F., the differential should not be less than 50° to 60° F.

(Note: This overall temperature differential, however, gives only part of the picture. Figure 7, for example, presents the spread

in internal temperatures between the fastest- and slowest-heating chub for a given run, as well as the temperatures underneath the skin for the fastest heating chub. Here the difference between the temperature at the center of the fish and the temperature underneath the skin represents the actual temperature differential driving heat toward the center. This temperature differential within the fish is substantially smaller than that between the smokehouse and the center of the fish, as is shown in figure 7. The temperature underneath the skin, in addition to being dependent on the smokehouse temperature, is also a function of the evaporation rate of moisture from the surface of the fish and therefore may vary greatly depending on such factors as air velocity and the moisture content of the air. Since this additional aspect complicates the picture, we have for simplification, considered the overall temperature differential--of smokehouse over fish--in our discussions, rather than the more variable and more difficult-to-measure temperature differential within the fish. Thus, each commercial processor employing steam or water-vapor injection and forced-air circulation should check the minimum temperature differential necessary to efficiently attain the regulation temperature of 180° F. for his specific installation.)

TOTAL PROCESS TIME: In the experiment on total process time, we studied the rate of loss of moisture and its effect on yield during a regulation process and also the effect on yield of air drying before and after processing. From the standpoint of cost and production, the total process time obviously should be as short as possible consistent with good quality and yield.

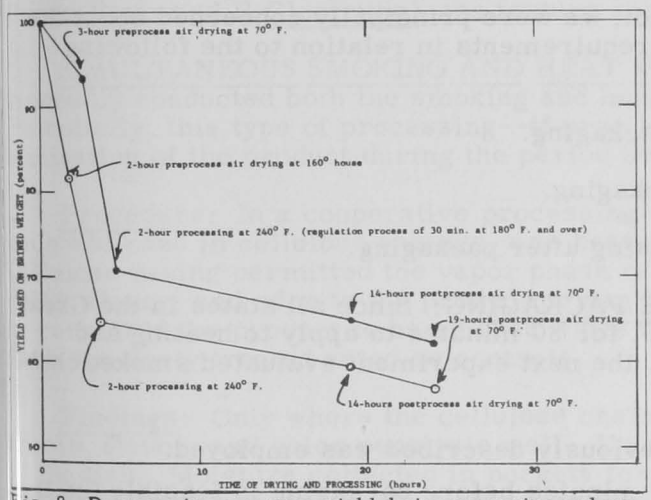

Fig. 8 - Decrease in percentage yield during processing and pre- and post process drying of chub.

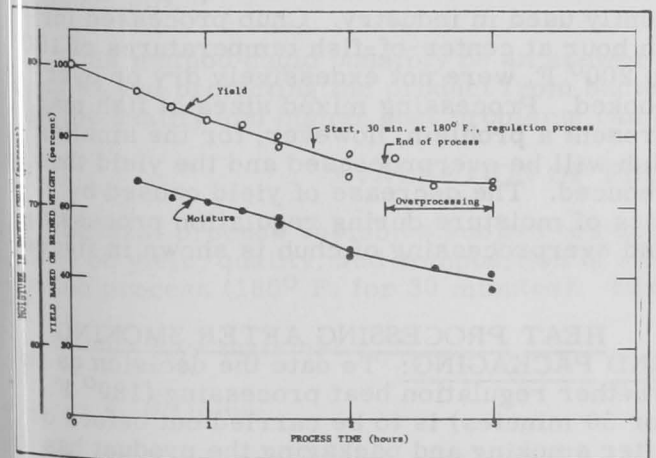

Fig. 9 - Decrease of percentage yield and moisture during regulation process and overprocessing of chub.

Procedure: The same processing procedure described under sections "Smokehouse Heat-Input Requirements" and "Differential Between Fish Temperature and Smokehouse Temperature" was followed. This general procedure was combined with pre- and post-process drying of chub.

Findings: Slow, prolonged processing as a result of inadequate heat input significantly

Fig. 10 - Weighing chub for yield studies.

reduced yield and undesirably dried the product. Predrying at low temperatures reduced final yield without accomplishing any useful purpose. For the required process temperature of 180° F., the optimum processing procedure would appear to be rapid heating with simultaneous smoking instead of smoking separately as has been industry practice in past low-temperature smoking operations. For highest yield, the total time that the chub is exposed t heat should be kept at a minimum. Figure 8 demonstrates that the loss of moisture takes place continuously before, during, and after processing. To avoid loss in yield, the operator should package the smoked product immediately after it has been chilled to storage temperature. Holding the chilled fish overnight before packaging may result in a 5- to 6-percent loss in yield. Figure 9 shows that the rates of loss in moisture and yield are fairly uniform throughout the regulation process.

SMOKEHOUSE-TEMPERATURE UNIFORMITY: Adequate forced-air circulation and good baffling in the smokehouse are essential in order to avoid undesirable hot and cold spots. Even-heat distribution is of concern to management from the standpoint both of processing regulations and of product uniformity and yield.

Grading for size in order to provide a uniformly processed product accordingly merits consideration.

PRODUCT ACCEPTABILITY

In ascertaining the acceptability of the product, we were principally concerned about the effect of the current regulation thermal-process requirements in relation to the following three variables:

1. Heat processing and smoking before packaging.
2. Heat processing after smoking and packaging.
3. Simultaneous smoking and heat processing after packaging.

HEAT PROCESSING AND SMOKING BEFORE PACKAGING: Since all states in the Great Lakes area interpreted the requirement of 180° F. for 30 minutes to apply to heating and smoking chub before rather than after packaging, the next experiment evaluated smoked chub processed according to those regulations.

Procedure: The same general procedure previously described was employed.

Findings: Processing chub at 180° F. for 30 minutes before packaging is feasible (on the basis of resultant yield and quality), although this temperature probably cannot be attained at the center of the fish with the equipment currently used in industry. Chub processed for an hour at center-of-fish temperatures of 18 to 200° F. were not excessively dry or overcooked. Processing mixed sizes of fish may present a problem, however, for the smaller fish will be overprocessed and the yield thus reduced. The decrease of yield caused by loss of moisture during regulation processing and overprocessing of chub is shown in figure 9.

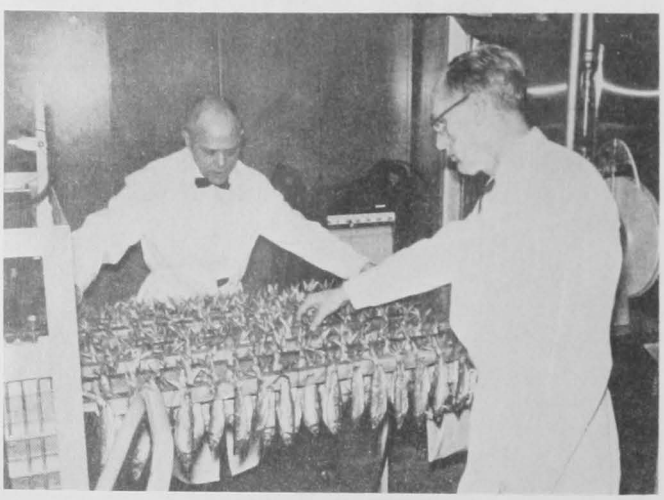

Fig. 11 - Quality evaluation of chub after smoking.

HEAT PROCESSING AFTER SMOKING AND PACKAGING: To date the decision as to whether regulation heat processing (180° F. for 30 minutes) is to be carried out before or after smoking and packaging the product has not been agreed upon by all regulating agencies. Since our earlier experiment dealt with

the effect on quality of heat processing before packaging, the next experiment determined the effect on quality of regulation heat processing after packaging. We investigated the effect on quality of processing at higher temperatures--204° F., which presumably is adequate to destroy Clostridium botulinum Type E within about 10 minutes (a short-time-high-temperature pasteurization process, slightly more effective than the 180° F. for 30-minute process); and 245° F., which is adequate to destroy Types E, A, and B within about the same time (a sterilization process).

Procedure: Two separate sets of smoked samples in flexible film (vacuum) and in aluminum foil were rapidly steam-retorted at retort temperatures of about 250° to 255° F., which were reduced as necessary to hold internal fish temperatures at about 204° F. or 245° F. for the time intervals required to achieve either the estimated partial or complete sterilization.

Findings: Sterilization after smoking adversely affected the smoked flavor, producing an inferior product. In partially steam-sterilizing individual smoked chub inside the package (in aluminum foil, and in flexible film with vacuum) for about 10 minutes at an internal temperature of 204° F. (F_o = .02,[1] which is estimated to be adequate to destroy Clostridium botulinum Type E), we found not only that the texture and smoked flavor changed significantly, though not seriously, but that any rancidity initially present in the frozen chub stock was accentuated. When individual smoked chub were fully steam-sterilized inside the package for 11 to 12 minutes at about 245° F. internal temperature (F_o = 6 plus, adequate to destroy Types E, A, and B Clostridia), the texture and smoked flavor were seriously affected.

SIMULTANEOUS SMOKING AND HEAT PROCESSING AFTER PACKAGING: We simultaneously conducted both the smoking and heating process after the product had been packaged. Potentially, this type of processing--if practical--could eliminate the hazard of bacterial contamination of the product during the period between smoking and packaging.

Procedure: In a cooperative processing experiment with industry, one group of chub, each enclosed in cellulose casings, was heat processed and smoked simultaneously. (The cellulose casing permitted the vapor phase of the smoke to penetrate the material and impart color, flavor, and odor to the product during heat processing. This technique thus theoretically permitted the product to be smoked while in the package.) A second group of unpackaged chub similarly treated acted as controls.

Findings: Only where the cellulose casing was in immediate contact with the fish did smoke, flavor, and color penetrate well. Upon removal, the casing tended to stick to the skin of the fish. Moisture collected in pockets formed by the casing, although fluid could be released during processing by making a small opening at the bottom of the casing. Comparisons between control and cellulose encased fish indicated that the latter retained more moisture and salt.

This method could possibly be an answer to processing smoked fish at 180° F. for 30 minutes and protecting the product from bacterial recontamination after smoking provided that the quality and higher cost problems can be resolved.

EVALUATION OF PROCESSING VARIABLES

Several process variables subject to control by the processor were evaluated for their effect on yield, quality, and composition of smoked chub, all within the framework of the regulation process (180° F. for 30 minutes). These included:

1. Raw material.
2. Brining.
3. Acid treatment.

[1] F_o serves as a commercial standard whereby the sterilizing effect of different processes may be compared under standardized conditions.

RAW MATERIAL: We studied the effect of variability in initial quality, size, and composition of the chub on the ultimate quality and yield of the smoked product prepared in accordance with the regulation process.

Procedure: Three lots of chub of significantly different initial freshness were regulation smoked. The first lot consisted of eviscerated chubs, mostly No. 2 or medium, bulk-frozen in 50-pound blocks with an ice glaze. This lot was to have been typical of commercial frozen stock. Its quality, however, was highly variable, and much of it was very poor. The second lot, which was frozen unglazed in plastic bags holding about 40 pounds, again consisted of eviscerated chubs taken by a commercial vessel. These fish were more uniform in size and of somewhat better quality. The third lot was caught by a U. S. Bureau of Commercial Fisheries exploratory vessel and frozen in plastic bags in 5-pound lots. Some bags held mostly large fish (three to the pound), and others held small; all were superior in quality to the other two lots. The general processing was similar to that used in earlier experiments.

Samples of the raw fish before and after brining and of fish after smoking, were analyzed for moisture, oil, and salt (chlorides).

Findings: The raw and the smoked chub varied widely in both composition and quality. Even fish of uniform size varied in composition, but the large fish usually had relatively more oil. In general, size, quality, and the composition of the fish all affected the absorption of salt and the other changes in the product that occurred during smoking.

The oil content of the smoked chub depended not only upon fish size (large fish were 2 to 3 percent higher in oil) but also on the extent of their drying during smoking. The percentage increase in oil content caused by drying was partly counteracted, however, by loss of oil by drip. The oil content of all samples was usually in the range of 7 to 15 percent. Moisture content depended to some degree on the extent of brining, but mainly on the drying caused by the thermal process and by the preprocess and postprocess handling. As expected, larger fish gave higher yields than smaller fish. This fact again emphasizes the importance of close grading for size before smoking.

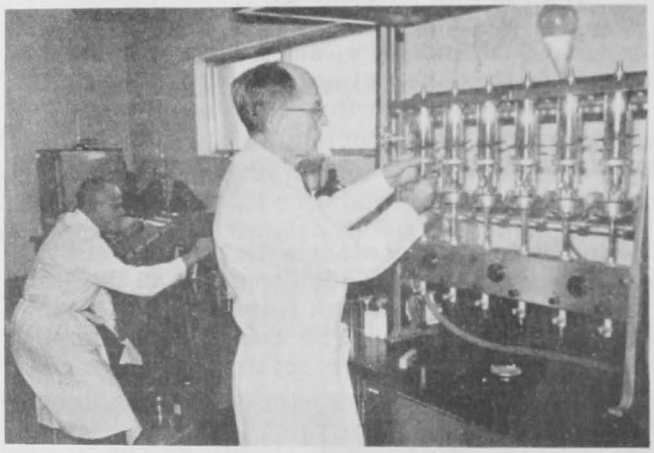

Fig. 12 - Oil-extraction apparatus.

When the heat input was sufficient to enable the processing to be completed within 2 hours, the yield of smoked product was 68 to 73 percent of the brined weight. Slow heating, overprocessing, or air drying, either before or after smoking, reduced the yield to about 55 to 65 percent.

Chub of initially poor quality or those that subsequently became poor in quality while in frozen storage gave a less desirable smoked product and lower yields. Oxidative rancidity was clearly apparent immediately after smoking in the more poorly preserved frozen chub.

BRINING: We studied the effect of various brining conditions on the ultimate quality and yield of the smoked product in relation to the regulation process.

Procedure: Some lots of chub were brined overnight in 20° to 30° salinometer brine in accordance with industry practice. Other lots were placed in stronger brines (50° and 70° salinometer) for 1 or 2 hours. Another lot, involving 11 sublots, was brined in concentrations ranging from 0 to 100° salinometer (saturated). All lots were given the regulation process.

Findings: On the basis of taste-panel tests, 2 to 3 percent salt in the smoked product appeared to be the acceptable range for most consumers. Smoked products in this salt range

Fig. 13 - Taste-panel evaluation of chub for salt level and quality.

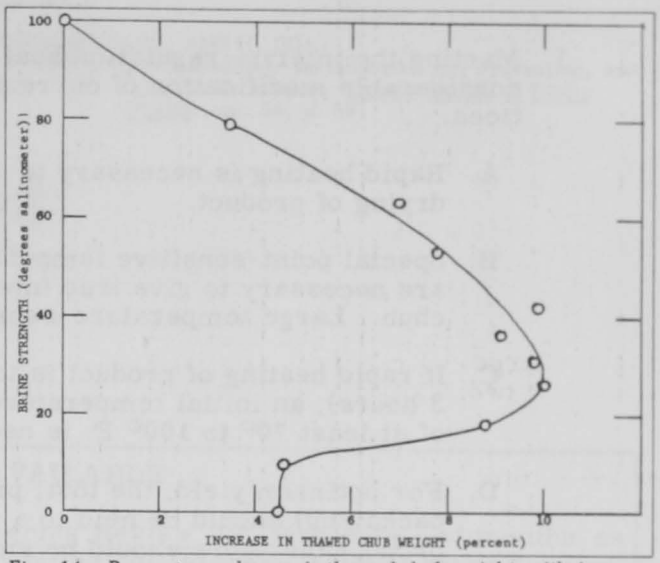

Fig. 14 - Percentage change in thawed chub weight with increasing strength of brining solution (18-hour brining time).

required a salt content of about 1 to 2 percent before being smoked. Brining chub overnight (16 to 18 hours) in 20° to 25° salinometer brine or for 2 hours in 40° to 50° salinometer brine usually resulted in a satisfactory level of salt in the smoked product.

In the test using 11 brine concentrations, the fish gained weight in all lots but the one involving saturated brine. As expected, the uptake of salt during brining depended largely on the concentration of brine and duration of brining. The maximum increase of 10 percent in chub weight occurred in brines of 25° and 30° salinometer (fig. 7). Figure 15 shows the percentage increase of salt content in brined and smoked chub with increasing strength of brining solution.

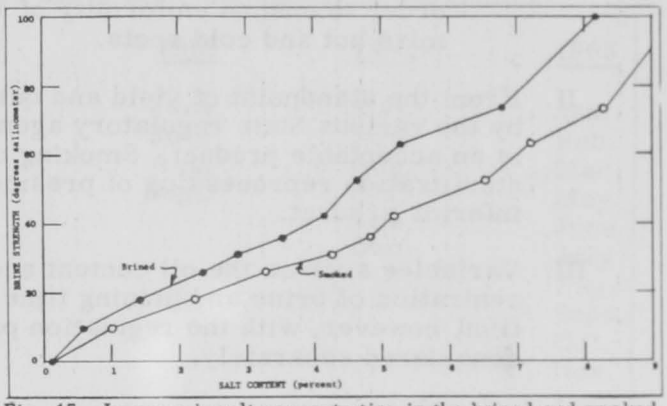

Fig. 15 - Increase in salt concentration in the brined and smoked product with increasing strength of brining solution (18-hour brining time).

ACID TREATMENT: We studied the feasibility of increasing the acidity of the meat of smoked fish to a pH at least 4.0 by an acid pretreatment as a means of inhibiting Clostridium botulinum growth (Type E toxin has been demonstrated, however, in pickled herring of pH 4.0 to 4.2 at 23° C., Dolman, Chang, Kerr, and Shearer, 1950; and Dolman and Iida, 1963.) We recognized that the buffered nature of the fish tissues would present difficulty in lowering the pH of the product. To answer several requests from industry for such data, however, and to estimate the resulting effect on the quality of the product, we carried out experiments with several acids that are sometimes used in food products.

Procedure: The following acid-brine treatments were tried: 10-percent acetic acid for 1 hour, 5-percent acetic acid for 18 hours, 2-percent phosphoric acid for 2 hours, 5-percent lactic acid for 16 hours, and 2-percent lactic acid for 16 hours. Controls were run with each set of acid-treated fish.

Findings: When the acidity of the smoked fish product was increased significantly by employing acetic, phosphoric, or lactic acids during the brining operation, the quality was impaired. Texture and flavor acceptability decreased markedly as did also the yield. Increasing the acidity by decreasing the pH of the smoked product to 4.0 or lower therefore appears to be impractical.

CONCLUSIONS

I. Meeting the interim-regulation heat process (180° F. for 30 minutes) will require considerable modification of current commercial processing equipment and practices.

   A. Rapid heating is necessary to ensure good yield and to avoid excessive drying of product.

   B. Special point-sensitive temperature measuring devices (thermocouples) are necessary to give true internal temperatures for small fish such as chub. Large temperature-sensitive bulbs give false readings.

   C. If rapid heating of product is to be achieved (process time of less than 3 hours), an initial temperature differential (of smokehouse over fish) of at least 70° to 100° F. is needed.

   D. For optimum yield, the total process time (from presmoking through packaging) should be held to a minimum consistent with quality. The product therefore should be smoked, cooled, and packaged rapidly.

   E. Forced-air circulation and baffling in the smokehouse are essential in order to ensure uniformity of smokehouse temperature and thus minimize hot and cold spots.

II. From the standpoint of yield and quality, smoked chub heat processed as specified by the various State regulatory agencies (180° F. for 30 minutes outside the packag is an acceptable product. Smoking of chub after packaging, or pasteurization or sterilization reprocessing of presmoked chub after packaging, however, yields an inferior product.

III. Variables such as the oil content and size and quality of the raw fish affect the con centration of brine and brining time needed. These process variables do not conflict, however, with the regulation process as such--that is, each variable must be considered separately.

   A. Chub vary widely in size, composition, and quality. These variables all affect salt uptake during brining and product behavior during smoking.

   B. Two to 3 percent salt in the smoked product appears to be an acceptable range for most consumers.

   C. Decreasing the pH of smoked fish to 4.0 or lower appears to be impractical from the standpoint of product quality.

FUTURE CONSIDERATIONS

Although the current interim regulations adopted by State regulatory groups are feasib from the standpoint of quality and yield and probably will give greater protection to the pro uct than before, the actual degree of microbiological safety for a product mishandled durin distribution (for example, held at a storage temperature higher than recommended) is at present unknown.

We anticipate that the Bureau's microbiological contract work will shed light on this aspect of the problem. Several different ways of attacking it are being tried simultaneousl Results of the Bureau's efforts in this field will be disseminated as rapidly as each phase o the work is completed.

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