PRELIMINARY INVESTIGATIONS ON THE FLAVOR OF FARMED CHANNEL CATFISH (*ICTALURUS PUNCTATUS*)

by

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INTRODUCTION

Catfish are well-known food fish. There are around 1,250 species, about 50 of which are found in North America (Lee, 1971). They usually inhabit warm, quiet, slow-moving waters. Most are found in fresh water but some species grow in salt water.

Channel catfish (Ictalurus punctatus) belong to the common freshwater species. They grow in large rivers and lowland lakes but they adapt readily to new environmental conditions (Anonymous, 1970a). Because of their flavor, adaptability and rapid growth, channel catfish show potential for fish farming.

Catfish farming is a booming industry in the United States. Today, about 50,000 acres of land are devoted to intensive catfish culture as compared to 26,000 acres in 1968 and 250 acres in 1960 (Ayers, 1971). The catfish farming industry forecasts that by 1980, about 245,000 acres of land will be under catfish production to meet the market demand for 1.3 billion pounds of channel catfish (Lee, 1971).

One of the problems of catfish farming is maintaining good fish quality. Many instances have been reported wherein off-flavors described as "musty," "earthy" or "muddy" were found in farmed catfish (Lovell, 1970; Greenfield, 1971; Nichols and Lacewell, 1971). These off-flavors may be associated with muddy water, algae blooms in the ponds, overfeeding, organic matter, chemicals or any combinations of these factors (Lee, 1971; Nichols and Lacewell, 1971). However, little research has been conducted to study them.

As part of a research on catfish metabolism, a study of channel catfish flavor was initiated at Kansas State University (KSU) in 1970. The study was originally designed to determine if flavor differences exist in channel catfish previously maintained on 3 different diets. Because muddy aroma and

flavor were observed in the first fish samples examined, some changes in the program became necessary.

Investigations were carried out in four phases, the first being an orientation phase. To rid the fish of the "muddy" aroma and flavor found in the first phase, a fasting treatment was conducted as Phase II. The effects of commercial freezer storage on the flavor of channel catfish frozen by liquid nitrogen spray was assessed in Phase III. Other aspects studied in this phase due to preliminary findings in the orientation phase include: (1) flavor and aroma differences between fish cooked from the frozen state and those allowed to thaw overnight under refrigeration prior to cooking, and (2) flavor and aroma differences among different sites of the same cooked fish. Phase IV involved a feeding experiment to determine effects of two diets (turkey liver and a processed floating feed) on catfish flavor. Throughout the study, examinations were conducted by schooled tasters experienced in the descriptive method of analysis employed.

REVIEW OF LITERATURE

Fish have long been an important source of food for man. However, little research has been conducted on fish flavor. The following review of literature includes the importance of fish as food and studies on fish flavor. Because freezing is the common method of preserving fish, effects of freezing and freezer storage on fish flavor and texture are reviewed. Some off-flavors in fish related to those found in the present study also are included.

Fish as Food

Nutritional Value. In general, fish contain between 15-24% protein, which, like other animal proteins, are complete and well-balanced (Jacquot, 1961; Tarr, 1969). The amount of fat in fish varies from less than 1% in lean

fish like cod and haddock to about 20% in fatty fish like salmon and mackerel (Shewan, et al., 1953). Inclusion of fish in the diet offers a method of increasing its protein content without appreciably increasing the amount of total fat. For developing countries where protein malnutrition is prevalent, fish and fishery products may serve as ideal supplements to diets traditionally based on cereals and low in proteins (Borgstrom, 1962).

Fish Consumption in the United States. The Food and Agriculture Organization (FAO) of the United Nations reported a world fish production of 56.2 million tons in 1969. It predicted the world's need for fish will rise to 100 million tons by 1985. In the same report, the United States production of fish was 2.5 million tons valued at $518 million.

Per capita consumption of edible fishery products in the United States in 1969 was 11.1 pounds (Anonymous, 1970b). This was the highest consumption in the country since 1954 and was attributed to the increase in the supplies of fillets and fresh and frozen fish. However, such fish consumption was less than that of other flesh foods in the same year: 39.9, 64.6, and 109.6 pounds for chicken, pork and beef, respectively (Lee, 1971). Thus, one of the goals of the fish industry in the United States, particularly that of the rapidly growing channel catfish industry, is to increase consumption of fish.

Fish Flavor

Fish Flavor Research Problems. Fish flavor constitutes an almost wholly neglected field of research as shown by the scarcity of information on the subject. One of the reasons for this may be fish are perishable and thus, difficult to work with. They rarely are eaten in a truly fresh state. Fish usually pass through some ice-refrigeration processes before being frozen,

dried or heat-processed. Spoilage and subsequent flavor deterioration in fish pose a unique problem because ice-refrigeration processes successful in retarding the growth of bacteria associated with meat products of warm-blooded animals are not satisfactory for retardation of the growth of organisms involved in the spoilage of cold-blooded animals (Shewan et al., 1953).

Problems in flesh flavor and odor research are dynamic due to the influence of feed, age, sexual development, season, species, and varieties within species (Tarr, 1966). Aside from these factors, considerable change in fish flavors may be brought about by: (1) the frequently long distances between the points of capture and consumption of fish; (2) variations in treatments received between these points; and (3) inherent differences in fresh flavors and keeping qualities of different species (Jones, 1961).

Odor and Flavor Characteristics of Fish. Many types of odors and flavors occur in fish. Stansby (1962) noted that there is no predominant odor that is the fishy odor. The term "fishy," he pointed out, is ambiguous. It is used to describe products other than fish, e.g., sometimes butter and poultry are said to be fishy.

There is little descriptive material on fish flavor. In 1953, Shewan and his co-workers developed what may be the first precise descriptive material on progressively deteriorating fish, as a basis for taste panel evaluation of quality (Table 1, Appendix). The loss of raw odors was described after the disappearance of "fresh, seaweedy odors." This neutral odor then was followed by odors indicative of progressive deterioration until "nauseating, putrid, faecal odors" were reported for spoiled fish. Many attributes of the raw odor are carried over through the cooked odor to the flavor, indicating raw odors influence the over-all flavor of fish.

Stansby and Jellinek (1964) reported a list of terms describing the flavors and odors most commonly observed in fish and fishery products at the Technological Laboratory of the U. S. Bureau of Commercial Fisheries, Seattle, Washington (Table 2, Appendix). The types of odors and flavors included in the list are far from complete. Many types, such as musty and cheese-like, which only occur occasionally or under abnormal handling conditions, are not included in the classification. In edible fishery products, researchers have found the range of odors and flavors from fresh to spoiled occurs in approximately the following chronological order: natural species odor and flavor (N), green (G), sweet (S), amine-like (A), early oxidation types (O), and putrid or spoiled (P).

Chemical Composition of Fish as Related to Fish Flavor. Jones (1967) noted that literature on the chemistry of fresh and not-so-fresh fish muscle is extensive but little attempt has been made to relate chemical composition to flavor. He divided fish flavor constituents into two main groups, nitrogenous and non-nitrogenous compounds. Amino acids and peptides, amines and ammonia, mononucleotides and their derivatives, and other nitrogenous bases make up the nitrogenous group. The non-nitrogenous group consists of volatile carbonyls, alcohols, free lower fatty acids, volatile sulfur compounds, carbohydrates and sugar phosphates.

Nitrogenous Compounds. Jones (1967) cited findings that certain amino acids contribute to fish flavor independently of other fish constituents. For instance, glycine added sweetness while a "meaty" character was related to histidine. Free amino acids also may act as precursors of other flavorous compounds when they undergo carbonyl-amino reactions in dehydrated, frozen or canned fish.

Amines, particularly trimethylamine, have been related to the "fishy" character of fish. Nononucleotides and their derivatives are flavor enhancers. For example, inosine-5'-monophosphate contributes to the "meaty" flavor of fish muscle (Jones, 1961).

Other nitrogenous compounds like pyridine, piperidine, pyrollidine and aminovaleric acid also have been identified in fish muscle. By admixture of these compounds with each other and with other compounds like mercaptans, indole and trimethylamine, the odors of freshwater fish, sea fish, "rather old fish," "fish-shop smell," putrid fish, and dried fish have been simulated.

Non-nitrogenous Components. Jones (1967) also noted that volatile carbonyls of low molecular weight are associated with fresh fish flavor while those of higher molecular weight are related to spoiling fish flavor. Flavors of lower fatty acids have been reported in spoiling fish like cod while sulfur compounds such as hydrogen sulfide, dimethyl sulfide, methyl mercaptan and organic sulfides have been found in spoiled fish.

The characteristic sweetness of fresh fish is due to the high initial glucose concentration in the muscle (Jones, 1961). Sugar phophates also contribute to the sweetish-salty character of fresh sea fish.

Hashimoto (1965) reported a study conducted by Japanese researchers on the taste-producing substances present in three marine products common to Japan. Various compounds such as glutamic acid, adenosine monophosphate, adenosine triphosphate, and inosine monophosphate were isolated from the marine products and tested for their taste-producing role. A combination of the above given compounds was found to imitate the "meaty" flavor of the natural extracts of the marine products studied.

Some Factors that Influence the Flavor of Fish.

Species and Source or Environment. Baldwin et al. (1961) studied the flavor of three species of fish (walleye, northern pike and carp) taken from four freshwater sources: a cold, deep lake; a shallow, mixed water lake; and flowages above and below the entry of effluent from industrial plants. Fish were sampled four seasons of the year. Differences were found in the flavor and aroma of fish according the water source from which they were taken. For all the fish examined, lower flavor and aroma scores were given for those taken from the source below the entry of effluents from industrial plants. Fish from the lakes had higher scores. Among the species studied, higher scores were given to walleye. Relatively low flavor and aroma scores were given to carp, regardless of the source. The terms "fishy" and "musty" were used to describe carp from all sources.

Palatability of carp, flathead catfish, and freshwater drum from different sites on the Mississippi River also was studied by Baldwin and her co-workers (1970). At certain periods of the year, the flavors of these three species were affected adversely by water pollution. Extent of flavor damage was influenced by fish species and proximity to source of pollution. Lower flavor scores were given for fish taken from the site nearest the source of pollution. Freshwater drum was more susceptible to flavor changes apparently related to the environment than were carp and flathead catfish. Fish aroma also was affected adversely by pollution of the water but to a lesser extent than flavor. Scores for aroma of the polluted water were not significantly correlated with palatability of the fish. However, it was noted that additional experience may have been needed by the judges in assessing aroma of polluted water.

Size and Body Area. Different trends among the species of fish in regard to size and flavor relationship were found by Baldwin et al. (1961). For northern pike, big fish within a source for a season were scored higher in aroma than small fish. On the other hand, within a season and location, small carp scored higher in flavor and aroma than big ones. For walleye, no significant correlation between size and flavor was found.

In another study, Baldwin et al. (1969) reported higher flavor scores for small flathead catfish (average weight - 1 lb. 4 oz.) than for big ones (average weight - 23 lbs. 3 oz.). Small carp weighing 3 lbs. on the average scored lower than big ones averaging 8 lbs., in contrast to previous findings. Less clear-cut differences were found among flavor scores for freshwater drum of different sizes. In the same study, different sites of the fish (i.e., anterior, middle and posterior) were examined for flavor differences. Flavor and aroma scores within each sex and species were not significantly different except the anterior portion of male carp was scored significantly higher in aroma compared to the posterior portion. It was suggested that further studies on positional difference in flavor and aroma be conducted in relation to sex and species of fish.

Preparation Procedure. The effect of the presence of skin or bone during baking on fish flavor was investigated by Baldwin et al. (1962). No consistent trend was found to relate presence of skin or bone to flavor scores of baked carp, northern pike, and walleye. The flavor of walleye samples which were flour-dipped and pan-fried was compared with baked walleye flavor in the same study. Fried samples scored higher than baked samples. However, the descriptive terms applied to both fried and baked walleye indicated that general impressions of fish flavor were not affected

substantially by the method of cookery. Unusual flavor characteristics, when present, seemed to be apparent regardless of the method of cookery.

Baines et al. (1969) studied conditions of thawing and cooking frozen fish which would optimize the ability of a taste panel to detect flavor differences. The procedure they adopted for taste panel work involved thawing whole fish or fillets overnight at 5 and 2.5 C (41 and 36.5 F) respectively, and cooking fish samples in a closed casserole over boiling water for 30 minutes.

Jones (1961) noted that cooking fish by steam in closed vessels minimizes loss of volatiles, while baking or deep-fat frying results in some loss of these components. He also observed that deep-fat frying, as frequently practiced in Great Britain, may completely mask most fish flavors.

Methods Used in the Sensory Evaluation of Fish Flavor.

Numerical Scoring Method. A numerical scoring system was used by Baldwin et al. (1961, 1962, 1969, 1970) for taste panel evaluations on fish flavor. Baked fish samples were rated on an 8-point scale for flavor and aroma, where 1 = extremely poor and 8 = excellent. In addition, taste panelists recorded a word description of any outstanding flavor and aroma found.

Quality Scaling Methods. As referred to earlier, Shewan et al. (1953) developed descriptive material with a corresponding scoring scale for sensory assessment of the progressive spoilage of cod fish stored in ice (Table 1, Appendix). Classification of quality factors was given in numerical form to ease handling and interpretation of sensory data. Using this system, a panel was trained to agree in assessing the quality of any one cod fish sample. With the accuracy attained by the panel, samples were clearly differentiated in terms of storage periods in ice under certain standard conditions, to

within a day or two. This quality scaling system has been used regularly at the Torry Research Station in Scotland.

A taste panel technique for evaluating eating quality of frozen cod was developed by Baines et al. (1969). A score sheet for cooked frozen cod was prepared (Table 3, Appendix). As preliminary work, persons trained in using the scoring system of Shewan et al., mentioned above, examined cooked samples of cod from a wide range of icing and frozen storage histories to compare the odor, flavor, and textural characteristics of iced and frozen fish. Unlike ice-stored cod, the predominant odor and flavor in frozen-stored cod could not be characterized by reference to a single odor or flavor, or groups of commonly encountered odors and flavors. Thus, the term "cold storage odor and flavor" was coined and a 6-point intensity scale was given where 0 = absent and 5 = very strong. In the same manner, the panel studied textural characteristics of cooked frozen cod and developed intensity scales for firmness and dryness. In addition, provision for additional texture descriptions together with a list of terms commonly used to describe texture, was made in the score sheet. A 9-point hedonic scale for over-all acceptability also was given.

Subsequently, the panel attempted to score cooked frozen code of different degrees of freshness prior to freezing; freshness odor and flavor scales as given by Shewan et al. were used. The panel was able to distinguish between cooked samples frozen at different initial degrees of freshness. Freshness scales developed by Shewan et al. for cooked unfrozen cod also were found useful in evaluating freshness of cooked frozen cod.

By means of this scoring system, Baines and his co-workers noted it was possible to distinguish and assess reasonably accurately the various attributes which make up the quality of frozen cod samples. Together with

the quality scaling system developed by Shewan and his co-workers for unfrozen cod, this scheme for frozen cod is reported to be in regular use at the Torry Research Station.

Flavor Profile Analysis. The Flavor Profile Method was applied to sensory analysis of fresh sea fish in Germany by Jellinek (1965). Aroma and flavor characteristics of cod, coal-fish and Norway haddock were investigated. Raw and cooked fillets, as well as gills, were analyzed by a trained panel. Because fish were graded into four classes - S, A, B, C (S = fancy, C = unfit for human consumption) - by inspectors in the German fish market, characteristic aroma and flavor components of each of these classes were worked out for each of the three species. At least 20 profiles were made for each species and each class and when final profile results were compared by class and species, the same descriptions, intensities, and order of appearance were found by the trained panel (Jellinek, 1965). For example, for the gills of cod belonging to the S class, a green grassy odor was found to be characteristic while for the gills of coalfish of the same class, the green odor was described as more similar to the odor of green, unripe apples. Because of the reproducibility of results, this method has been found useful in establishing standards for comparison in fish quality evaluation.

Effects of Freezing and Freezer Storage on Fish Flavor and Texture

Freezing and freezer storage, common means for preservation of fish and fishery products, bring about some changes in odor, flavor and texture. These changes and the rate at which they occur depend on the quality and condition of the raw material and handling and processing techniques employed before, during and after freezing.

Pre-freezing Considerations. When fish die, they undergo chemical and physical changes that affect their quality in the fresh state as well as their suitability for subsequent freezing and freezer storage (Slavin, 1968). Prior to freezing, autolysis resulting from the activity of naturally occurring enzymes in fish muscle may take place. With short-term chill storage prior to freezing, a loss of flavor may be brought about through action of autolytic systems which cleave flavorous compounds (Jones, 1969).

As with any type of food material, over-all quality of frozen fish greatly depends on initial freshness of the raw material. Source of fish, season, and various biological factors, such as composition and structure of the flesh, also influence frozen fish product quality (Dyer and Peters, 1969).

Freezing Considerations. Investigators agree that during freezing of fish, water present in the muscle in free form freezes out as crystals of pure ice. Such a change in state brings about substantial chemical and physical changes in fish (Zaitsev, 1965). As water crystallizes, salt levels in the remaining moisture associated with proteins in the tissues become progressively concentrated, thus lowering the freezing point of the tissues. Maximum ice crystal formation occurs between -0.8 to -5 C resulting in a very slow freezing rate at this zone (Dyer and Dingle, 1961). After this zone, moisture in the cells becomes much less and denaturation of the proteins may occur.

Protein denaturation has been related to the tough texture of frozen fish and fishery products. Textural deterioration and protein denaturation were associated by Reay as cited by Connell (1969) with decreased protein extractability in frozen-stored fish. Lower protein solubility in frozen fish muscle also was related to protein denaturation (Nikkila and Linko, 1956).

Changes in total protein extractability (and solubility) often parallel changes in the texture or flavor of thawed, cooked fish; measurement of these quantities, therefore, could be used as an objective method of assessing eating quality of frozen fish (Connell, 1969).

Rate of Freezing. The influence of the rate of freezing on fish muscle properties has been studied extensively but only in relation to biochemical changes that occur in the tissues. Little work has been conducted to relate freezing rate to fish product quality as judged by organoleptic means.

During rapid freezing of fish, smaller ice crystals are formed throughout the tissues compared to those formed during slow freezing. Large ice crystals formed during slow freezing may rupture the cells in fish muscle, causing increased drip formation when the product is thawed (Borgstrom, 1968).

Reay as cited by Dyer (1951) found greater protein denaturation in slow-frozen than in rapid-frozen fish. The zone of maximum ice crystallization was passed more rapidly during fast freezing than during slow freezing. On the other hand, Love (1958, 1962) found that proteins of fish frozen at intermediate rates of freezing (within the range of commerical practice) became inextractable at a faster rate than those of fish frozen at rapid or slow rates. He identified this critical range of freezing as one where either a single crystal is formed intracellularly in each cell or ice formation occurred extracellularly, conditions which were particularly more conducive to protein damage due to the pattern of ice formation. Love suggested that indications of relative toughness should always be obtained from a taste panel because the relation between toughness and protein (extractability) is not a simple one, expecially at low freezer storage temperatures. With a freezing time of 220 minutes for cod muscle, 88.2% of

the proteins were shown to be soluble, a value just a little below that of fresh fish (95-96%), but the muscle was found tough by a taste panel. Textural characteristics of frozen fish may be affected by factors other than protein denaturation (Love, 1956).

Freezing Time. If initial fish quality is high, a freezing time of several hours to as long as 24 hours does not significantly affect the quality of the frozen product (Slavin, 1968). Dyer and Dingle (1961) cited the work of Notewarp and Heen who found little difference in taste quality measurements of cod frozen in 15 minutes, 80 minutes or 8 hours, the time required to pass through the critical zone of maximum crystal formation.

The State of Rigor. When fish die, organic compounds which supply the energy for muscle contraction slowly decompose and at a certain critical level, the muscle contracts, entering a state known as rigor mortis (Love, 1968). During rigor mortis, fish muscle is tough and cells are dry. After the resolution of rigor, muscles relax and tissues become more moist.

The condition of fish when frozen, as related to the state of rigor affects the texture of the processed product. Nikkila and Linko (1954) observed that freezing during rigor mortis rendered proteins more prone to denaturation during subsequent thawing than fish frozen after the resolution of rigor.

When pre-rigor herring were frozen and stored at -20 C, protein solubility decreased appreciably during the first 10 days and hardly increased in 30 days of storage (Nikkila and Linko, 1956). This is in contrast to fish frozen post-rigor and stored at the same temperature; protein solubility was initially high and remained constant during the storage period, indicating less protein denaturation. These workers recommended freezing fish after they have passed through the state of rigor. On the other hand,

Love (1962) found that if fish are frozen before the onset of rigor, they suffer less protein damage during subsequent storage than fish frozen post-rigor and stored under the same conditions. (Love measured the amount of dexyribonucleic acid (DNA) liberated from cells ruptured during freezing and freezer storage as an index of protein denaturation.) However, differences in protein extractability between pre- and post-rigor fish may exist before storage; storage, in fact, may introduce no further effects (Connell, 1964). Considering these findings, Banks (1965) cited the need for more research on controlling the onset and duration of rigor mortis in fish muscle.

Post-freezing Considerations. Most of the adverse changes in frozen fish result not from the freezing process itself but rather through storage of the frozen products (Nikkila and Linko, 1956). Connell (1969) enumerated the following texture-related changes that occur during frozen storage: (1) alterations in the appearance of cut surface; (2) development of an increasing tendency to lose moisture on thawing; and (3) development of an increased impression of firmness, toughness, and dryness when the thawed and cooked fish is eaten. These changes were directly attributed to changes in proteins.

Storage Time and Temperature. Quality and storage life of frozen fish products are influenced greatly by the storage time and temperature. Investigators agree that the lower the storage temperature, the longer the frozen product can be stored without much detectable loss in quality. Conversely, storage above 0 F results in a rate of quality loss that is accelerated as the storage temperature is increased (Lane, 1964). Fluctuating storage temperatures also affect quality adversely (Nikkila and Linko, 1956).

Effects of storage temperature on quality may differ with different species of fish (Slavin, 1968). With fatty species such as mackerel and herring which are especially susceptible to oxidative rancidity, storage at -20 F (-29 C) or lower has been found necessary to obtain satisfactory quality and good marketing shelf-life. In lean species such as cod and haddock which are not susceptible to oxidative rancidity, storage at 0 F (-18 C) or -10 F (-23 C) has been found adequate.

Banks (1965) observed that storage of fish at 14 F (-10 C) prevents bacterial growth but does not stop enzymatic action. Fish stored at this temperature lost their natural flavor rapidly and took on unpleasant off-flavors. To limit enzymatic changes over long storage periods, a storage temperature of -22 F (-30 C) was recommended.

Thawing. The properties of thawed fish for cooking depend on the thawing method as well as freezing and storage conditions. During thawing, if the water formed from melted ice crystals is reabsorbed by the tissues, thawed fish will have properties similar to fresh fish (Zaitsev, 1965). However, if most of this water oozes out of the tissues or if there is large drip formation, the thawed fish becomes dry, fibrous and unpalatable.

Some Off-flavors in Fish

The Earthy or Muddy Taint. Thaysen (1936) investigated the nature of the earthy or muddy taint in fish when salmon in a big river in Great Britain were contaminated with this taint. Water samples from the river where tainted fish were obtained had off-odor similar to that of the fish. When contaminated fish were boiled in potable drinking water, the cooking water acquired the earthy or muddy taint and the off-odor came out in the steam. It was concluded that the offending substance was caused by some compound in the flesh which was soluble in water and volatile in steam.

Analysis of the river water samples showed abundance of certain types of actinomycetes, bacteria which have been reported to produce an odor frequently described as earthy or muddy. Cultures of these odoriferous species of Actinomyces were grown. The odoriferous compound was isolated; it was partly soluble in alcohol and soluble in ether. In concentrated form, the isolate gave a penetrating manurial odor.

With Pentelow, Thaysen (1936) subjected untainted fish to water solutions containing 1, 2, 10, 20 and 40 parts per million of distillate of the Actinomyces species. After one hour in the solutions, fish were killed and cooked by boiling. In every instance, fish acquired marked earthy and muddy flavor and aroma. At higher concentrations of distillate, the taint was nauseatingly strong; with more dilute solutions, the taint was slight but the flesh was described as definitely unpalatable. Control fish did not acquire any earthy or muddy flavor.

Further investigations were carried out by the same workers to study removal of the off-flavor. After tainted rainbow trout were kept in a "clean" pond for a week, the muddy flavor was not perceptible in cooked fish flesh. When some contaminated fish were kept in aerated tanks supplied with a continuous flow of clean river water, no diminution of taint was found after 27 hours, some was lost after 3 days, and no muddy taint was found after 5 days.

Thaysen and Pentelow (1936) were not able to relate muddy off-flavor to mud. Trout exposed to heavy suspensions of taint-free mud for several hours emitted no earthy or muddy taste or smell before or after being cooked. The cooking water also was taint-free. It was concluded that earthy or muddy taint in fish is not brought about by mud <u>per se</u> but by a substance from some odoriferous species of Actinomyces which are sometimes present in mud.

A study was conducted by the same workers to determine how fish get the taint. Dead fish were placed in water solutions containing distillate of the odor-producing substance. They did not acquire the muddy flavor but live fish subjected to the same treatment did. Using a rubber balloon, it was possible to confine a fish so that its head and gills were exposed to one solution and its body to another. Fish breathing contaminated water invariably acquired a strong earthy flavor while fish breathing "clean" water but with their bodies exposed to the tainted solution did not acquire the off-flavor. It was suggested that the taint enters fish principally through the gills and is carried to the muscle through the blood stream.

Odors and Flavors Produced by Algae. Palmer (1959) reported that algae are considered the most frequent causes of tastes and odors in water supplies. A few species of algae are well known for producing specific distinctive tastes and odors. In lakes and in permanent and semi-permanent pools, algae especially of the blue-green group, may grow so abundantly as to produce a surface scum or "water bloom" (Smith, 1950). Decay of this frothy scum produces disagreeable odors and tastes in aquatic animals (Olive, 1918). Certain plankton forms of algae are sometimes used as food by fish fry.

Five types of typical odors produced by algae in water were listed by Palmer (1959): aromatic, fishy, grassy, musty and earthy, and septic. Aromatic odor was described as being similar to a certain fruit or vegetable, e.g. geranium, nasturtium, violet, muskmelon and cucumber. Others in this category were described as spice-like, objectionable, like skunk or garlic odor. Fishy odor was attributed to large numbers of the same algae responsible for aromatic odor. Grassy odor also was produced by algae present in large numbers, usually green algae, but also blue-green algae and pigmented flagellates. Musty and earthy odor was associated with Actinomyces and a

few species of algae. The earthy odor of water and soil was related to the presence of actinomycetes; musty odor was associated with some blue-green algae. Musty also was described as "potato bin" and "moldy." Terms used to describe the odor of water, such as weedy, swampy, marshy, peaty, straw-like and woody, may be modifications or combinations of grassy and musty odors. Abundant growth of blue-green and occasionally green algae has been associated with septic odor, also described as pigpen, foul, objectionable, vile and putrefactive.

Off-flavors in Catfish: Causes. The following conditions are possible causes of off-flavors in catfish: (1) excessive plankton bloom, (2) presence of muskgrass, (3) overfeeding, (4) decaying organic matter, (5) use of chemicals, (6) muddy water, and (7) feeds high in fish byproducts (Lee, 1971). Lee noted that fish grown and held in muddy water acquire an unpleasant, muddy taste. Blue-green algae, when present in abundance, give off a foul, musty odor and cause water to smell sour. Muskgrass, a group of algae which grows in the bottom of ponds, also has a disagreeable, musty odor which is passed on to fish.

Overfeeding may cause off-flavors in two ways: (1) excess feed may turn sour and catfish will absorb the sour feed flavor; and (2) excess feed in the water will enhance the growth of algae which in turn may produce off-flavor in fish (Lee, 1971).

EXPERIMENTAL PROCEDURES

Phase I

Materials. Channel catfish from the following lots were seined from fish ponds at the Tuttle Creek Fisheries Research Laboratory, Manhattan, Kansas, in September, 1970:

Pond No.	Code	Age Group
4	R	I
6	X	I & II
7	N	I

From each of the fish groups, 100 fish were isolated for this work. The average weight for channel catfish of Age Group I is 107 g. and of Age Group II is 280 g. (Tiemeier, 1966).

Preparation of Samples. Immediately following seining, most of the fish were killed, eviscerated and individually wrapped in heavy duty aluminum foil (gauge .0015). Samples were labeled, packed in ice and transported to the laboratory at Justin Hall, KSU. Other fish samples were transported alive in a container of pond water for subsequent dressing in the laboratory. Unless scheduled to be tested within a few hours of being dressed, samples were held refrigerated or frozen (laboratory walk-in freezer at -15 to 5 F).

Because muddy aroma and flavor were found upon initial examination of X fish samples, 12 fish from Pond 6 were transferred for purging to a 20-gallon glass tank fed by a continuous flow of well water and under constant aeration. These fish were examined for aroma and flavor and 11 and 18 days of treatment in the aerated tank. In addition, periodic samples of Pond 6 water for algae counts were obtained using a pint jar attached to a plankton net. Water samples were preserved by 10 ml. of formaldehyde and refrigerated until counted. Algae counting followed the method of Bonneau (1970) as described in the Appendix, page 51.

Continuing the orientation work, R and N fish were prepared and examined separately but in parallel. Samples were examined after refrigeration and after freezer storage. Some of the frozen samples were cooked after overnight thawing under refrigeration (standardized to approximately 24 hours throughout this study) while some were cooked from the frozen state.

Cooking Method. In all phases of this study, fish samples were cooked by steaming to allow inherent aromas and flavors to be perceptible at their maximum intensities. One weighed fish was steamed at a time on a perforated metal rack set over boiling deionized, distilled water in a covered pan. The fish were considered done when they flaked easily. The following cooking intervals were roughly determined according to weight of the thawed fish sample: 5 min. for less than 50 g.; 10 min. for 50-150 g.; 12.5 min. for 150-250 g.; 15 min. for 250-300 g.; and 17.5 min. for 300-350 g. For fish cooked from the frozen state, an additional 5-10 min. cooking time was employed. Fish weighed from 30-325 g.

Flavor Examinations. Examinations were conducted by the project leader and two trained tasters in a quiet, well-lighted and relatively odor-free laboratory.

Fish samples were examined hot in preheated, covered casseroles. Usually, one fish was examined at a time; two fish of a given group per session. Aroma was checked first; then flavor. Small bite-size samples were taken from four specific locations: belly side (ventral to lateral line at anterior end), top side (dorsal to lateral line at anterior end), and two portions of the tail (dorsal and ventral to the lateral line), as shown in Figure 1. (The silver-gray subdermal layer covering the samples was scraped away before tasting.) Observations made by the taste panel were given in descriptive terms.

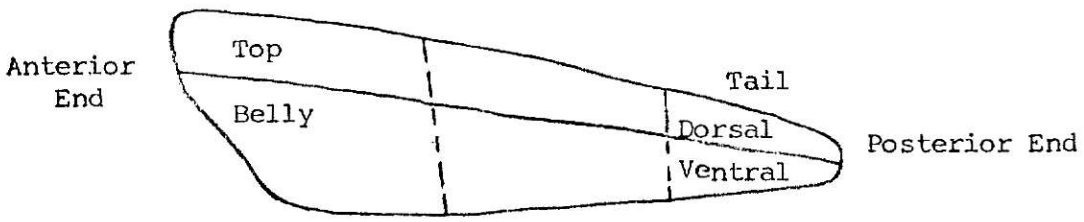

Figure 1. Sites of the fish examined by the flavor panel.

Phase II

Materials. Due to weather conditions, all test fish remaining from Phase I were taken from the ponds and transferred to 150-gallon metal tanks which were aerated and fed by a continuous flow of well water. Different fish groups were kept in separate tanks and no feed was given.

Preparation and Examination of Samples. Samples from each fish group were obtained after 11 days in the tank, were dressed, wrapped and transported according to the standard procedure described in Phase I. Some samples were refrigerated while others were frozen in liquid nitrogen spray in the Meat Science Laboratory, Weber Hall, KSU. The "flash" frozen samples were stored in the walk-in freezer at Justin Hall.

Because 11-day tank samples of X and R fish were found to be earthy in aroma and flavor, these two groups were sampled after 18 and 21 days, and together with N fish after 32 and 39 days of tank treatment. X fish, which were consistently found to have off-flavor, were examined after 9 weeks in the tank.

Examination of samples was conducted by the same panel as in Phase I. As before, two cooked fish samples from a given group were examined in a session; one fish at a time. Frozen samples were thawed under overnight refrigeration prior to testing, unless indicated otherwise.

Phase III

Materials. Test fish in this phase were X fish of Age Group II which had been kept without feed in aerated metal tanks for three months. These fish were part of those left from Phases I and II.

Preparation of Samples. Forty-six dressed and wrapped test fish were transported in insulated ice chests to the Meat Science Laboratory. All fish

samples (except three which were to be refrigerated overnight for use as control samples) were flash frozen simultaneously in 18 minutes. The foil-wrapped frozen samples were immediately vacuum-sealed in 3 mm. Iolon (Du Pont) plastic film, two samples to each sheet of film measuring about 8 X 11 inches. The vacuum-sealed frozen samples were then transported in insulated ice chests to the Manhattan Ice and Cold Storage Plant and stored in a freezer locker maintained at -5 to 5 F. Samples were periodically taken for examination according to the schedule set up in coordination with the flavor panel (Table 4, Appendix). Sometimes the entire flavor panel conducted the examination; at other times, only the project and panel leaders did. The author served as the panel leader.

Test fish were taken from the freezer locker a day prior to examination. Samples to be cooked from the thawed state were thawed overnight in a laboratory refrigerator; samples to be cooked from the frozen state were kept in the freezer compartment of the same, home-type refrigerator. As before, samples were cooked by steaming.

Flavor Examinations.

Panel. Examinations were made by the project and panel leaders, and by a panel which also included five graduate students in Foods and Nutrition enrolled in a course in applications of food flavor analysis. The seven panel members were trained tasters and had experience in the descriptive method of flavor analysis employed.

Method of Analysis. The Flavor Profile Method was employed. This involves an analysis of aroma, flavor-by mouth and feeling sensations when a food is taken into the mouth and prepared for swallowing. Over-all impression or amplitude is recorded first, followed by individual character notes in their order of appearance and intensity. In addition aftertaste, or any sensations in the mouth after swallowing, is recorded.

Amplitude or over-all impression involves all the qualities of the character notes and all the qualities of the basic character, which together create the general flavor effect (Caul, 1957). It is observed in both aroma and flavor and is rated on the following scale, gauged according to the product under study:

)(very low
1 low
2 medium
3 high

Character notes or the perceptible factors are defined in descriptive terms. These are perceived through standardized techniques of smelling and tasting the product. A simple constant scale is used to indicate the intensity of each character note:

0 not present
)(threshold or just recognizable
1 slight
2 moderate
3 strong

The symbols + or - are sometimes affixed to the intensity rating to indicate a level between two intensities. For instance,)(+ could indicate a level between)(and 1 but closer to)(while 1- could indicate another level between)(and 1 but closer to 1. Intensity ratings, 0 -)(and ½ also were used in this study; 0 -)(to indicate just barely recognizable intensity, and ½ to indicate a rating midway between)(and 1.

Panel Procedure. The project and panel leaders together examined one fish at a time; two fish per session. One fish was cooked from the frozen state; the other from the thawed state.

The seven-member panel was randomly divided into three groups each session. Two groups with two members each, and a group with three members, examined one fish at a time; two fish per group per session. All panel sessions were 50-60 minutes in duration.

Orientation. Three orientation sessions were held to:

1. acquaint the panel with channel catfish flavor,
2. develop standard techniques for examining fish samples,
3. develop terminology descriptive of the product.

During this time, panel members examined frozen channel catfish kept in freezer storage from 2-4 months. After closed panel sessions in which each panelist recorded her aroma and flavor findings on a response sheet, open discussions of the findings followed. Differences in terminology were discussed and suggestions for reference materials were given. As a result, panel members examined such reference materials as boiled spinach, boiled parsley, and wet earth from a flower pot.

Analysis of Samples. Fish refrigerated overnight served as control or "fresh" samples. As shown in the schedule (Table 4, Appendix), frozen samples were examined after 5 days of freezer storage. Because of the limited number of samples (43), examinations were conducted at 2-week intervals after the first two weeks of storage. As fish showed signs of aging after 12 weeks of freezer storage, samples were examined weekly (except during the 15- and 16-week periods when the panel leader was not available.)

Samples were examined according to the standard procedure developed during orientation. Aroma was examined first while the sample was still hot in the covered casserole. Each panelist partially slid off the casserole cover and sniffed the sample 2-3 times; the casserole was kept covered for a short while between times.

One member of the group examining a sample then scraped off the silver subdermal layer covering the fish and served the other taster(s) small bite-size samples from four specific locations in the following order: belly,

top, dorsal and ventral sides of the tail. For each of the specific sites of the fish, amplitude, individual flavor notes perceived in their order of appearance, and the intensity of each, were reported. In addition, any aftertaste was noted. Demineralized, distilled water at room temperature was used as a mouth rinse as needed.

In addition, the panelists, without being told which ones were the frozen and thawed samples, were asked to characterize differences, if any, between samples examined each session.

Phase IV

Materials. Test fish used were from three previous feed groups kept in separate aerated metal tanks without feed for three months. These were left from Phases I, II and III of this study. Fish were pooled together and stocked into two heated tanks, A and B. Throughout the experiment, the temperature of the water in the aerated tanks was maintained at 70 F.

Frozen turkey liver, thawed overnight under refrigeration prior to use, was used as one diet. The other was a 25%-protein processed floating feed manufactured by Doan Feed Products Company.

Preparation and Examination of Samples. Feeding of both fish groups was started with turkey liver; this was to accustom the fish to feeding after being without feed for three months. After a month of liver-feeding, floating feed was used together with the turkey liver to see if the fish would feed on the floaters. They did, and after another three weeks when the fish were feeding well, the actual feeding experiment was started.

Because many of the fish in tank B had died (cause(s) of death can only be speculated upon; the stress of being without feed for so long and being transferred from one tank to another may have been too much for the fish), only the fish in tank A, divided into two groups, were used. One

group was kept in tank B. Fish in tank A were fed floating feed; fish in tank B were fed turkey liver.

After 19 days of feeding, a sample from each feed group was taken for examination after overnight refrigeration. Three samples from both groups were examined after Day 21 by the seven-member panel as in Phase III.

Because fish in tank B were diminishing in number again, all the fish were taken after almost 5 weeks of feeding. By then, only 5 fish were left in tank B so only 5 paired examinations comparing the feed groups could be conducted. One pair was examined when the fish were freshly caught, three pairs after overnight refrigeration, and the remaining pair after 2 days of refrigeration. Examination of the samples was conducted by the two-member panel as in Phase III.

RESULTS AND DISCUSSION

Phase I

Orientation. Observations made during the orientation phase are summarized in Table 5 (Appendix). X fish taken directly from Pond 6 smelled and tasted muddy (Set 1). Two and three weeks later, despite no feeding and decreasing water temperatures, pond fish still tasted muddy (Sets 7, 8 and 9). Eleven days of tank treatment failed to purge X fish of off-flavors (Sets 2 and 3); 18 days of treatment was effective (Sets 4, 5 and 6).

Treatments before cooking appeared to be important. Fish developed fishy aroma and flavor upon refrigerated storage (Set 4 vs. 5). Samples cooked from the frozen state (Set 6) tasted more like freshly caught fish (Set 4) than did those of the same lot cooked after 3 days' refrigeration (Set 5).

R and N fish required no tank treatment; aromas and flavors of the cooked fish provided no off-notes (Sets 10 and 15). However, R fish from the same catch frozen in a home-type freezer and held for a month and more (Sets 12, 13 and 14) emitted such flavor notes as lemony and earthy, which may be classed as off-notes. For N fish treated similarly, a lemony flavor note appeared after a month of freezer storage (Set 17), and earthy, later (Sets 18 and 19). Holding both R and N fish in the refrigerator showed 5 days to be unacceptable practice (Sets 11 and 16).

Fish frozen in a home-type freezer and stored may have had slightly poorer flavor when cooked from the frozen state than when cooked from the thawed state (Set 13 vs. Sets 12 and 14; Set 18 vs. Sets 17 and 19).

Table 5 does not offer sufficient data on "food" flavored fish to determine flavor differences among the three fish groups. Nor is it possible to deduce flavor differences between age groups.

As indicated earlier, periodic samples of Pond 6 water for algae counts were obtained when X fish were found to be muddy in flavor and aroma. Algae counts and genera found in abundance on the date water samples were taken are shown in Table 6 (Appendix). One genus predominated at a certain period and another, later. Because of some sampling variations however, counts are relative and the results, therefore, are more qualitative rather than quantitative.

Anabaena, Pediastrum and Ceratium are taste and odor algae, i.e., they give off characteristic odors and tastes. Anabaena belongs to the blue-green algae group, Pediastrum to the green algae group, while Ceratium is in the flagellate group. Anabaena produces grassy, nasturtium-like musty odor when growth is moderate; when growth is abundant, a septic odor is given off (Palmer, 1959). Pediastrum is reported to produce a green, grassy odor while a pronounced fishy odor is associated with Ceratium.

X fish seined on September 14, September 25 and October 7, 1970, during the period when plankton samples also were taken from Pond 6 were found to have green, earthy and muddy aroma and flavor. The algae bloom in the pond at that time may have contributed to these off-flavors.

Phase II

Fasting Experiment. As stated earlier, fish from each group remaining from Phase I were transferred from the ponds to individual 150-gallon metal tanks of continuous flow, aerated well water. Feed had been withheld before transfer, and no feed was given during the time span of Phase II. Objective of this fasting treatment (duplicate of conditions for Phase I) was to eliminate any flavor differences among the three groups - differences caused by pond contamination or feed.

Phase I findings for X fish had shown muddy flavor before special treatment; earthy flavor after 11 days' treatment; and "clean" flavor after 18 days. Hence, samplings of Phase II fish were made at these 2 intervals (for purposes of replication) as well as after 3 and 4 weeks of tank treatment. In addition, 11-day fish were flash frozen and otherwise handled the same as Set 3 from Phase I. The objective was to compare the effects of slow and fast freezing. Table 7 (Appendix) summarizes findings for Phase II.

As in Set 3 from Phase I, 11 days' tank treatment failed to purge X fish of earthy aroma and flavor. Although pond samples of R fish in Phase I did not have any off-flavors a month before they were placed in the tank, earthy aroma and flavor were reported for 11 days of tank treatment. On the other hand, N fish which had no off-notes in Phase I did not produce earthy flavor after 11 days' tank treatment.

In Phase I, X fish slow frozen after 11 days of tank treatment did not give off earthy flavor as did refrigerated fish from the same lot (Set 3 vs.

Set 2). In Phase II, 11-day fish which were flash frozen but otherwise handled the same as Set 3 from Phase I had earthy flavor. These varied findings are not attributed to effects of slow or fast freezing but rather to differences in initial intensities of the earthy note prior to freezing. Phase I refrigerated 11-day samples had a flash of earthy flavor but no earthy aroma (Set 2). Phase II samples treated in the same manner were definitely earthy in aroma and flavor.

R fish flash frozen after 11 days of tank treatment had earthy flavor; N fish given the same treatment still did not give an earthy note.

After 18 days' tank treatment, X and R fish had flat flavor, X samples being just barely earthy while R's flavor had only a fleeting earthy aromatic. (N fish were not sampled because earlier they had no off-notes.) These findings indicate that X and R fish were being purged of their earthy flavor although purging still was not complete after this period in the tanks, as compared to findings in Phase I.

As another probe on the effects of fast freezing, 21-day tank samples of X and R fish were flash frozen. Whether cooked from the frozen or thawed state, R fish kept in freezer storage for 7 and 8 days still had earthy notes; so did X samples stored for 8 days. Since 21-day fish were expected to have less of the earthy note compared to 18-day fish, and they did not, flash freezing and storage for a short period may have produced "fresh" degradative changes.

After 32 days of tank treatment, X and R fish were still earthy; N fish were not. In addition, a rubbery note and/or odd flavor was perceived in all three groups. A rubbery note was also observed on live fish, particularly near the cloaca. It was attributed to the rubber hose through which well water was conducted to the tanks; a plastic hose was therefore provided.

A week after the rubber hose was replaced, the rubbery note and odd flavor had disappeared; X and R fish again had earthy flavor; N fish did not.

These observations strongly suggest that cooked catfish flesh (probably including fat) can emit odor and flavor compounds present in the water in which the fish live, especially if the fish are not being fed. These findings are in agreement with those in the literature in cases where muddy fish were associated with muddy water (Thaysen, 1936) and fish with poor flavor were associated with polluted waters (Baldwin et al., 1961, 1970).

Because X fish were consistently found to have earthy flavor through 39 days, samples were taken after 9 weeks of tank treatment. By then, they gave just a barely earthy note. Purging in this case (and undoubtedly for R fish) may have been slow because population in the tank was dense.

Phase III

Effects of Freezer Storage. When they are not to be deep-fat fried, breaded or marinaded, commercially available frozen fish are generally cooked from the frozen state. Effects of commercial freezer storage on the flavor of channel catfish cooked from the frozen state will be discussed first; then cooking from the thawed state will be considered. Tables 8 and 9 (Appendix) summarize findings for the control or "fresh" samples and frozen samples, respectively.

The muddy flavor of the control fish was lost on freezing. Green, earthy and/or spinachy flavor appeared in its place; these notes were found intermittently in the flavor picture during the study.

The fresh character of the fishy note disappeared after 2 weeks of storage. Total flavor decreased progressively until the sixth week when a suppressed flavor described as "sat-upon" (practically nil, expected to be off soon) was noted. The 8-week samples gave the first impression that the

fish were aging. Flavor amplitude ratings then varied, being somewhat higher when earthy, green or fish-oily notes were found, and lower when these notes were absent or barely perceptible. After 10 weeks of storage, varying degrees of "old" fishy character were noted: sometimes it was described as "not fresh but not really old"; at other times it was called "stale," "getting old," or finally, just old. After 20 weeks of storage, fish samples were found to have stale and old fishy flavor.

Sweet taste seems to play a big part in the over-all flavor of channel catfish. When present, sweet appeared early together with the fish identity. After 19 weeks of storage, sweet was barely perceptible and at 20 weeks, it was not reported at all.

Some differences in the flavor of different sites of the same cooked fish were found: the belly lost its sweet taste sooner than the top and tail; earthy and fish-oily notes were found in the tail more often than in the belly and top; the tail often had higher amplitude compared to the top and belly. There were only slight differences between the belly and the top, and between the dorsal and ventral sides of the tail.

Effects of Thawing Method. A comparison of the aroma and flavor factors of fish cooked from the frozen (F) and thawed (T) states is shown in Figure 2 (Appendix). F and T samples did not show much flavor difference during the first month of commercial freezer storage. They both began to show flavor signs of aging in 8 weeks; after that, T samples were described as older in character compared to F samples. These findings give reason to the more convenient, current practice of cooking fish from the frozen state.

In this study, the flavor of the fish seemed to be based on three types of character notes: sweetness, fish identity, and environmental notes such as earthy, green and their variants. Figures 3a and 3b, respectively,

depict the changes in the sweet, earthy, and fishy notes of the F and T samples as storage time progressed.

For both F and T samples, all the above given notes progressively decreased in intensity until the 6-week storage period. At 8 weeks when a "getting old" fishy character was noted, a long-lasting earthy note and a stronger intensity of sweet taste together gave more total flavor to the F samples. During the same period, a fish-oily note contributed to the "getting old" fishy character of the T samples. After 20 weeks of storage, both F and T samples gave the following results: the sweet taste had disappeared; the earthy note was barely perceptible; and the fishy flavor was old.

Other Observations. Textural differences between frozen and thawed fish were observed by the panels. During the first 6 weeks of storage, findings were not consistent. At times, F samples were tough, T samples more tender; these reversed at other times. Such variations may be due to sample differences. Although intended, it was not always possible to have fish samples of about the same size or weight each session. Another source of variation may be the state at which fish samples were frozen; they may have been in different stages of rigor mortis.

After 8 weeks of storage when the fish flavors were described as "getting old", some textural changes were exhibited. The texture of both F and T samples were then variously described as mushy, chewy and stringy, and for want of better terms, "off" and "not quite right". These changes in texture indicate that as freezer storage progresses, changes in fish components occur constantly, and with these come some textural changes.

Although the amount of drip obtained upon thawing was not measured, there was little drip formed (about a few drops per thawed sample). However, as storage period progressed, the amount of drip seemed to increase.

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When absolutely fresh fish are frozen, stored, and thawed under optimum conditions, their histological structure differs only slightly from that of fresh fish so that little drip is formed upon thawing (Zaitsev, 1965). It was noted that changes in the protein of long-stored fish result in a large amount of fluid separation or drip, and some flavor compounds may be lost upon drip formation. In this study, T samples had more of an old character starting at 8 weeks or storage; this may indicate that some of the "more desirable" flavor compounds may have been lost during thawing, leaving the "off" notes or making them more evident.

After 18 weeks of storage when the aroma and flavor of both F and T samples were described as "stale", the presence of sticky juices during chewing also was reported. Watts (1961) noted that some off-odors in flesh foods often defined as "stale," "old," or "warmed over" are caused by lipid oxidation, especially in the cooked tissues of meat and fish. She also noted that lipids involved in this kind of deterioration are not of the adipose tissues but rather of the muscle tissues; that is lipoprotein. Hence, aside from some flavor changes due to lipid oxidation, some alterations in textural characteristics may accompany protein changes during prolonged freezer storage of fish muscle.

Another observation made by the panels was that bigger fish often seemed to have stronger intensities of the "less desirable" flavor notes: green, earthy, spinachy and muddy. A tongue feel, variously described as astringent, dry or metallic, was reported together with these notes.

Cold (room temperature) fish samples also seemed to have stronger intensities of the above notes. Sometimes, an old fishy character was perceived in cold samples which was not evident in hot samples. This points out the importance of controlling the temperature of samples for taste panel evaluation.

Phase IV

Feeding Experiment. Examinations of boiled samples of turkey liver and floating feed used as fish diets in this phase led to the following observations: (1) the liver aroma had some liver, gizzard and poultry character notes; (2) the liver had bitter taste; and (3) the floating feed aroma had a cereal or grain identity plus an off-note that could not be identified by association. The boiled floating feed was not examined for flavor.

Findings (Table 10, Appendix) indicate that after 19 days on turkey liver, fish showed properties indicative of their diet. These properties became more pronounced and total flavor was stronger as feeding continued. After Day 33, a distinct chicken or poultry character was reported for the turkey liver-fed fish.

With fish given floating feed, findings (Table 11, Appendix) show that after 21 days samples did not reflect feed properties in their flavor. However, after Day 33, the feed aromatic was noted in one flavor of all sites of the fish samples.

These observations, though made only on a limited number of samples, indicate that the aroma and flavor of cooked channel catfish can reflect the aroma and flavor properties of their feed or diet.

Other Observations. As stated earlier, five pairs of fish were examined after 33 days of feeding; one pair freshly caught, three pairs after overnight refrigeration, and the fifth pair after 2 days' refrigeration. This was conducted as a guide for possible consumer-type tests, considering the infeasible schedule imposed by dressing, cooking and testing freshly caught fish.

Tables 12 and 13 (Appendix) give the composite profiles of fish fed turkey liver and floating feed, respectively. The panel noted that freshly caught samples were tough and did not have much flavor compared to

refrigerated samples; freshly caught samples may have been in rigor mortis when cooked, hence the tough texture. Samples refrigerated for 2 days also had less total flavor compared to samples refrigerated overnight. These indicate that post-mortem changes constantly occur in fish muscle under refrigeration, influencing subsequent flavor development and breakdown.

The fact that fish refrigerated overnight had more total flavor than freshly caught or 2-day refrigerated samples also indicates that this sample age or treatment may be the better one for consumer-type tests.

SUMMARY AND CONCLUSIONS

Three groups of channel catfish previously fed different diets and taken from different ponds, N, R, and X, were subjected to a four-phased flavor investigation during the period from September, 1970 through June, 1971. When taken directly from their respective ponds, X fish had earthy and muddy flavors, although N and R fish did not. This finding altered the original aim of the project; namely, to determine if detectable flavor differences exist in channel catfish maintained on different feeds. Nevertheless, the investigation does permit some conclusions regarding channel catfish flavor as well as inferences relating to preparing and handling fish for consumer-type flavor tests. The following summation is given not in chronological order of investigation but rather so that bases for conclusions are evident.

Abundant growth of flavor- and odor-producing algae in the X fish pond during the fish sampling period may have contributed to the earthy and muddy aromatics and flavors.

Purging treatment of twelve X fish reduced off-flavors in 11 days and eliminated them in 18 days. In a subsequent experiment in which all fish from

the three ponds were subjected to a fasting treatment (similar to the earlier purging experiment), muddy-flavored fish lost their off-notes at a slower rate (after 9 weeks). Rate of purging, and therefore duration, probably depends on fish population density and initial strength of off-flavors.

During the fasting experiment, "rubbery" flavor found in the fish samples could be attributed to the rubber hose through which water was conducted to the banks, since replacement of the rubber hose by a plastic one eliminated the off-flavor. Odorous compounds in the water in which channel catfish live may be detected in the cooked flesh.

Good-flavored fish frozen in a home-type freezer and held for a month and more in storage developed earthy and lemon oil-type flavors. The combination of slow freezing and refrigerator-freezer storage (-15 to +5 F) brought about flavor changes. It is not possible to compare preservation effects of slow and flash freezing, since the flash-frozen fish were earthy and muddy before freezing. It may be significant that these flash-frozen fish did not appear to develop increased levels of earthy and muddy flavors during 4 weeks of commercial freezer storage (-5 to +5 F).

Another significant finding is that flash-frozen channel catfish started to show flavor signs of aging after 8 weeks of commercial freezer storage. Since these fish were frozen in the fresh state, vacuum-sealed and immediately stored, this finding tends to emphasize the perishability of fish as a food.

Thawing method could affect the flavor of freezer-stored channel catfish. During the first month of freezer storage, slow-frozen fish cooked from the frozen state had slightly poorer flavor than fish cooked from the thawed state; flash-frozen fish cooked from these states had similar flavor divergences. After 8 weeks of storage, flash-frozen fish cooked from the thawed state had the older fish character. Drip formation from thawed samples after prolonged

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storage may have resulted in the loss of desirable flavor compounds; hence, their poorer flavor. No comparison can be made with slow-frozen fish, since they were not held for the same duration.

Slight differences were observed among different sites of the same cooked fish. The flavor pictures of two anterior portions (belly and top) were similar but were different from tail portions, the latter usually having more total flavor. Dorsal and ventral sides of the tail were similar in flavor.

Channel catfish cooked after 24-hour refrigeration had more total flavor than freshly caught or 2-day refrigerated samples; but the difference probably was not any greater than the flavor difference between anterior and posterior portions of the same fish. Fish refrigerated for 3 days still were acceptable for testing; at 5 days, they were inedible. For consumer-type tests, which pose a "logistics" problem, 1, 2 or 3-day refrigerated fish may be used.

Channel catfish fed turkey liver and floating feed showed flavor properties of the respective feeds in their cooked flesh. This finding strongly suggests that besides odorous compounds in the water in which channel catfish live, properties of the fish diet may modify the flavor of cooked catfish flesh.

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APPENDIX

Table 1. Odor and flavor characteristics of raw and cooked cod (After Shewan, et. al.). Quality deterioration indicated by lower marking. Equal marks in (A), (B) and (C) do not necessarily indicate equal quality.

	Score
A. Raw Odor	
Fresh seaweedy odors	10
Loss of fresh seaweediness, shellfish odors	9
None, neutral	8
Slight musty, acetamide-like, milky, N-caprylic acid-like odors	7
Bready, malty, yeasty odors	6
Lactic acid, sour milk or oily odors	5
Some lower fatty acids (e.g., acetic or butyric) or grassy, slightly sweet, fruity odors	4
Stale, sour, cabbage water, turnipy or phosphine-like odors	3
Ammoniacal (trimethylamine and other amines) with strong toluidine-like odors	2
Hydrogen sulfide and strong ammoniacal odors	1
Nauseating, putrid, faecal odors, indole, ammonia, etc.	0
B. Cooked Odor	
Strong, fresh seaweedy odors	10
Some loss of fresh seaweediness	9
Lack of odor, or neutral odors	8
Slight strengthening of the odor but no sour or stale odor; wood shavings, woodsap, vanillin, or lipase-like odors; slight salt fish or cold storage odors	7
Condensed milk, caramel, or toffee-like odors	6
Milk jug, boiled potato, boiled clothes, or metallic odors	5
Lactic acid, sour milk, or toluidine-like odors	4
Some lower fatty acid (e.g., acetic or butyric acids), grassy, soapy, turnipy, or tallowy odors	3
Ammoniacal (trimethylamine and lower amines) odor	2
Strong ammoniacal (trimethylamine etc.) and some sulfide odors	1
Strong putrid and faecal odors (ammonia, indole, etc.)	0
C. Flavor	
Fresh, sweet flavors, characteristic of the species	10
Some loss of sweetness	9
Slight sweetness and loss of the flavor characteristic of the species	8
Neutral flavor, definite loss of flavor, but no off-flavors	7
Absolutely no flavor, as if chewing cotton wool	6
Trace of off-flavors, some sourness, but no bitterness	5
Some off-flavors and some bitterness	4
Strong bitter flavors, some rubber-like, and some slight sulfide-like flavors	3
Strong bitter flavors but not nauseating	1
Strong putrid flavors (e.g., sulfides) tasted with difficulty	0

Table 2. Flavors and odors in fishery products. (After Stansby and Jellinek, 1965)

Type	Description	Principal Source	Predominance as flavor (F) or odor (O) Primary	Secondary
A	Amine-like	Slightly stale to spoiled fish	O	-
B	Burnt	Fish oils and fish meals	O	F
F	Fresh water fish	Freshly caught fresh water fish in skin and to lesser extent in flesh	O	F
G	Green	Fish oils	F	O
I	Iodine-like	Certain species like sole, especially after they have been feeding upon some particular types of food	F	O
N	Natural species giving characteristic flavors and odors	Flesh and oil of many fish such as salmon and herring	F	O
O	Pure oxidation types	Fish oils and meals and oily fish especially after extended storage primarily in the frozen state	F	O
P	Putrid or spoiled; very obnoxious types of flavors and odors such as those derived from certain sulfur compounds	Spoiled fish and fishery products	O	F
S	Sweet; an intense sweet odor that at extremes may border upon the putrid but at low concentration is generally quite unobjectionable	Well-iced fish kept for a relatively long time	O	F

Table 3. Score sheet for cooked, frozen cod (After Baines et al., 1969)

Freshness odor and freshness flavor
Scored as for cooked, unfrozen cod
Cold store flavor and odor
0 Absent
1 Very slight
2 Slight
3 Moderate
4 Strong
5 Very strong
Firmness
0 Very soft
1 Softer than normal
2 Firm (normal 2 to 5 days iced unfrozen North Sea cod)
3 Slightly firmer than normal
4 Slightly tough
5 Tough
6 Extremely tough
Dryness
0 Sloppy, watery
1 Juicy, moist (normal fresh, unfrozen North Sea cod)
2 Slightly dry
3 Dry
4 Extremely dry
Additional texture descriptions
E.G., mushy, mealy, granulated coconut, fibrous, stringy, rubber bands, chewy, woody
Over-all acceptability
9 Like extremely
8 Like very much
7 Like much
6 Like slightly
5 Neither like nor dislike
4 Dislike slightly
3 Dislike much
2 Dislike very much
1 Dislike extremely

Table 4. Schedule for flavor examinations of frozen channel catfish

Date (1971)		Weeks in Commercial Freezer Storage
February	8	-1-P* (5 days)
	9	-1-P (5 days + overnight refrigeration)
	17	2-L**
March	3	4-L
	17	6-L
	19	6-P (+ 2 days)
	31	8-L
April	14	10-L
	16	10-P (+ 2 days)
	28	12-L
May	5	13-L
	12	14-L
June	2	17-L
	9	18-L
	16	19-L
	23	20-L

* P: Seven-member panel

** L: Two-member panel

Table 5. Summary of aroma and flavor findings for channel catfish, Orientation (Phase I: 9/9-10/30/70)

Set	Fish and Date Seined + Special Treatment		Age Group	Days of Storage		Observations	
				Frozen	Refrigerator	Aroma	Flavor
1	X	9/11	I & II	-	2	earthy, muddy	earthy, muddy
2	X Special tank -	9/14 11 days	I & II	-	3	fishy (fresh water fish identity)	flash of earthy
3	X	9/14	I	4	1	slightly fishy, green	sweet, lemony
	Special tank -	11 days	II	4	1	fishy	bland, fishy
4	X Special tank -	9/14 18 days	I & II	-	-	nothing much	slightly lemony, sweetish
5	X Special tank -	9/14 18 days	I & II	-	3	lemony, meaty, slightly fishy	fishy, lemony, meaty
6	X Special tank -	9/14 18 days	I & II	11	-	not much, just noticeable earthy	lemony, sweetish
7	X	9/25	I & II	-	3	earthy	muddy
8	X	9/25	I	4	1	earthy, muddy	muddy
			II	4	1	varied: earthy, muddy in one sample; lemony, meaty in another	same as aroma
9	X	10/7	I	14	-	fishy, green	earthy, muddy, fishy
			II	14	-	green	meaty, green, muddy
10	R	9/16	I	-	2	sweet, fresh fish identity	sweet, fishy, meaty
11	R	9/16	I	-	5	fishy, ammoniacal	-
12	R	9/16	I	29	1	fishy	lemony, meaty, earthy
13	R	9/16	I	37	-	fishy, earthy	sweetish, fishy, earthy
14	R	9/16	I	40	1	fishy, meaty, slightly earthy	lemony, earthy

Table 5. Concluded

Set	Fish and Date Seined + Special Treatment		Age Group	Days of Storage		Observations	
				Frozen	Refrigerator	Aroma	Flavor
15	N	9/16	I	-	2	fresh fish identity	sweet, meaty (spice-like)
16	N	9/16	I	-	5	fishy, ammoniacal	-
17	N	9/16	I	29	1	fishy, slightly meaty	sweetish, lemony, meaty
18	N	9/16	I	37	-	fishy, earthy	sweet, lemony, slightly earthy
19	N	9/16	I	40	1	fishy, meaty, slightly earthy	sweet, lemony, meaty, slightly earthy

Table 6. Algae counts of water samples taken from Pond 6 when fish samples were found to have muddy aroma and flavor

September, 1970

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15 2,723 Anabaena	16	17	18	19
20	21	22	23	24	25 4,139 Anabaena	26
27	28	29 Mostly Ceratium Some Anabaena + Pediastrum	30			

October, 1970

S	M	T	W	T	F	S
				1	2 991 Mostly Anabaena Some Ceratium	3
4	5	6	7 2,307 Mostly Pediastrum + Ceratium Some Anabaena	8	9	10
11	12	13 1,217 Mostly Pediastrum	14	15	16 835 Mostly Pediastrum	17
18	19	20 822 Mostly Pediastrum	21	22	23 298 Mostly Pediastrum	24
25	26	27 1,280 Mostly Pediastrum + Ceratium	28	29 612 Mostly Pediastrum + Ceratium	30	31

Table 7. Summary of aroma and flavor findings for channel catfish after fasting treatment (Phase II: 11/2/70 - 1/5/71)

Days in Tank	Fish (Age Group)		Days of Storage		Observations	
			Frozen	Refrigerator	Aroma	Flavor
11	X	(I)	-	3	earthy	fishy, earthy
11	R		-	3	earthy	meaty, earthy
11	N		-	3	green	fishy, lemony, sweet, meaty
11	X	(I)	4	1	fishy, green	earthy
11	R		4	1	fishy, (Pond water)	slightly earthy
11	N		4	1	fishy, green meaty	meaty, chicken-like
18	X	(I)	-	-	fishy	flat, just misses being earthy
18	R		-	-	fishy	fishy, flat (fleeting earthy aromatic)
21	R		7	-	fishy, green	flat, slightly earthy
21	X	(I)	8	1	fishy, green	meaty, earthy
21	R		8	1	fishy, green	just barely earthy, almost lemony, sweetish
32	X	(I)	-	-	green	earthy, odd flavor
32	R		-	-	fishy, green, rubbery	earthy, rubbery
32	N		-	-	fishy, rubbery	fishy, fatty, odd flavor
39	X		-	1	fishy, green	earthy, lemony
39	R		-	1	fishy, green	earthy
39	N		-	1	fishy	fishy
63	X		-	1	fishy, green	bland, fishy, just barely earthy

Table 8. Composite profile of control channel catfish for Phase III*

	Intensity
Aroma	
Amplitude 1	
fishy, fresh	1
spinachy	)(
muddy	)(
Flavor of Belly	
Amplitude 1+	
sweet	)(
fishy, fresh	½
muddy	1
Flavor of Top	
Amplitude 1	
earthy	½
fishy, fresh	1
Flavor of Tail, Dorsal	
Amplitude 1+	
sweet	)(
fishy, fresh	1
earthy	1
muddy	1
Aftertaste	
fishy	1
muddy	)(
Flavor of Tail, Ventral	
Amplitude 1+	
sweet	)(
fishy, fresh	1
earthy	1
muddy	1
Aftertaste	
fishy	1
muddy	)(

*Fish samples were kept in an aerated metal tank for 3 months without feeding.

Table 9. Composite profiles of channel catfish kept in commercial freezer storage for 5 days through 20 weeks and cooked from the frozen state (Phase III)

5 DAYS		2 WEEKS		4 WEEKS		6 WEEKS	
AROMA	1½		½		1		1
muddy	)(	fishy	1	fishy	1	fishy	1
fishy, fresh	½	green	)(				
green-spinachy	1						
FLAVOR OF BELLY			)(+		½+		)(
sweet	)(	sweet	½	fishy	½	sweet	)(
fishy, fresh	1	fishy	½	spinachy	)(	earthy	0-)(
green-earthy	)(	spinachy	)(	earthy	)(		
				tongue feel			
AFTERTASTE						bitter	0-)(
FLAVOR OF TOP	½		½		)(+		)(
sweet	)(	sweet	0-)(	sweet	)(	earthy	)(+
fishy, fresh	1	fishy	1	fishy	)(	fishy	½
green	)(+	spinachy	1				
AFTERTASTE							
tongue feel and drying						earthy	)(
FLAVOR OF TAIL, DORSAL	1+		½+		½		½
sweet	)(	sweet	)(	sweet	)(+	sweet	)(
fishy, fresh	1	fishy	)(			fish-oily	1-
earthy	1-	earthy	1			fishy	1-
		metallic feel					
FLAVOR OF TAIL, VENTRAL	1+		1		½		½+
sweet	½	sweet	)(+	sweet	)(	fishy	1-
fishy, fresh	1	fishy	)(+			fish-oily	1-
green	½	earthy	0-)(				
earthy	)(	metallic feel					

Table 9. Cont.

6 WEEKS + 2 DAYS		8 WEEKS		10 WEEKS		10 WEEKS + 2 DAYS	
AROMA	1½		1		1-		1-
fishy	1	fishy	1	fishy amine (fleeting)	)(	fishy (not fresh)	1-
green-spinachy	½			fishy	)(+	green-grassy	)(+
FLAVOR OF BELLY	1		1		)(+		1-
sweet	)(	sweet	)(+	sweet	)(	sweet	)(-
fishy	1	fishy	½	fishy	0-)(	fishy	1-
earthy	)(	earthy	)(			earthy	½+
tongue feel		tongue feel					
AFTERTASTE						fishy	½
FLAVOR OF TOP	1		1		½		1
sweet	)(	sweet	½	sweet	1-	fishy	1-
fishy	1	spinachy-fishy	)(+	fishy	½	sweet	½
						earthy	½
						green	)(+
FLAVOR OF TAIL, DORSAL	1		1+		)(+		1
fishy	1-	fishy (getting old)	1	sweet	1	sweet	½
fish oily	1	sweet	½	fishy	)(	fishy (getting old)	½
green	)(+	earthy	½	fish oily (getting old)	)(+	earthy	)(+
AFTERTASTE		tongue feel					
FLAVOR OF TAIL, VENTRAL	1		1		)(+		1
sweet	)(	sweet	½	sweet	)(	sweet	)(
fishy	1-	fish-earthy	1	spinachy-fishy	½	fishy (getting old)	1
green	)(+	earthy	1			earthy	1
earthy	1-						
AFTERTASTE		tongue feel					

Table 9. Cont.

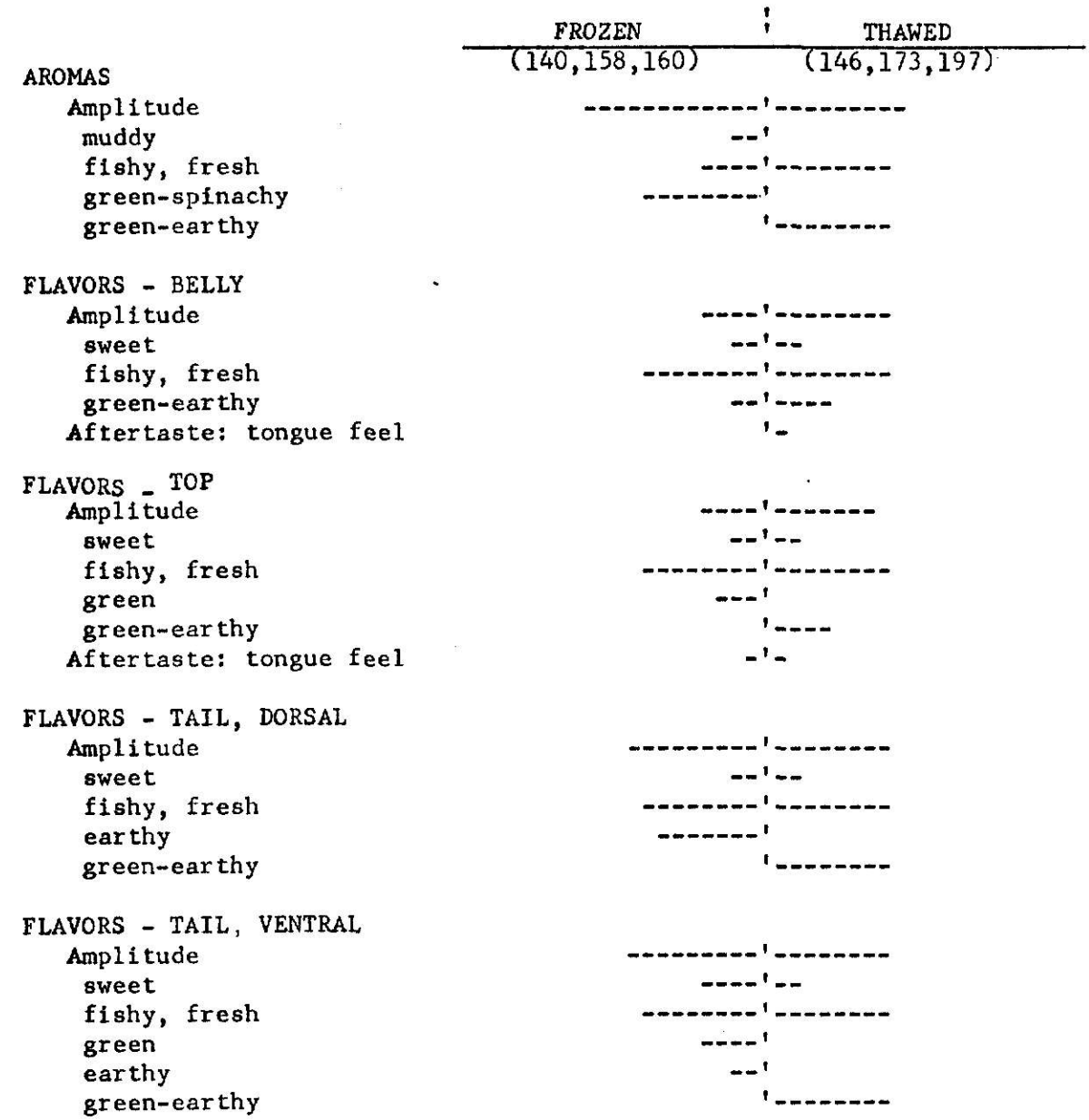
12 WEEKS		13 WEEKS		14 WEEKS	
AROMA					
	1-		1		1
fishy	½+	fishy	1	fishy	1
FLAVOR OF BELLY					
	½		)(+		)(
sweet	0-)(	fishy	½	fishy	0-)(
fishy	½			fishy, old	1
FLAVOR OF TOP					
	)(+		)(		)(
fishy	½	earthy (fleeting)	1	sweet	)(
		fishy	)(	fishy	)(
		sweet	)(		
FLAVOR OF TAIL, DORSAL					
	1		)(		)(+
sweet	0-)(	fishy	½	sweet	)(
fishy	½	earthy (fleeting)	1	fishy	)(+
fish-oily, old	)(	tongue feel		earthy	)(+
FLAVOR OF TAIL, VENTRAL					
	1		½		)(+
fishy	½	earthy	1	sweet	)(
fish-oily, old	)(	fishy	½	fishy	½
		sweet	)(	earthy	½
		tongue feel			

Table 9. Concluded

17 WEEKS		18 WEEKS		19 WEEKS		20 WEEKS	
AROMA							
	½		½		1		½
fishy	1-	fishy (getting old)	½+	fishy	1	fishy, old (fleeting)	1-
				green	)(		
				metallic	½		
FLAVOR OF BELLY							
	1-		)(+		)(+		)(
fishy	1	fishy	1-	sweet	)(	fish-oily	)(
green	)(	sticky serum		fishy	0-)(	nil flavor	
mouth feel				earthy	)(	(with "stale" impression)	
				nil flavor		sticky serum	
FLAVOR OF TOP							
	1-		½		)(+		)(
fishy	1	"stale" aroma		fishy	½	fishy	)(
sweet	0-)(	fishy	1+	sweet	)(	same as belly	
		sticky serum		earthy	)(	sticky serum	
				fishy, old	)(		
FLAVOR OF TAIL, DORSAL							
	1		1-		½		½
chicken-like aroma		fishy (getting old)	½	rubbery (fleeting)	)(	fishy	½+
sweet	½	"stale" aroma		fish-oily	1-	fish-oily (old)	)(+
fishy	1	sticky serum		nil flavor		earthy	0-)(
fish oily	1					sticky serum	
earthy	)(						
FLAVOR OF TAIL, VENTRAL							
	1+		1-		½+		)(+
chicken-like aroma		fishy (getting old)	½+	fishy	1	spinachy-fishy	½
sweet	½	earthy	)(	rubbery	)(	fishy, old	)(+
fishy	1	sticky serum		earthy	½	sticky serum	
earthy (fleeting)	1-					tongue feel	

FIGURE 2. Comparison of channel catfish cooked from the frozen and thawed states (Phase III)

a. Stored 5 days



( )-Weights of dressed samples

The number of dashes in each bar relate to the intensities of factors listed in Table 9 but do not transalte to an intensity symbol for slight, moderate and strong. The intensity scale was just expanded to present sample differences clearly. Character notes are listed at random.

FIGURE 2. (Cont.)

b. Stored 2 weeks

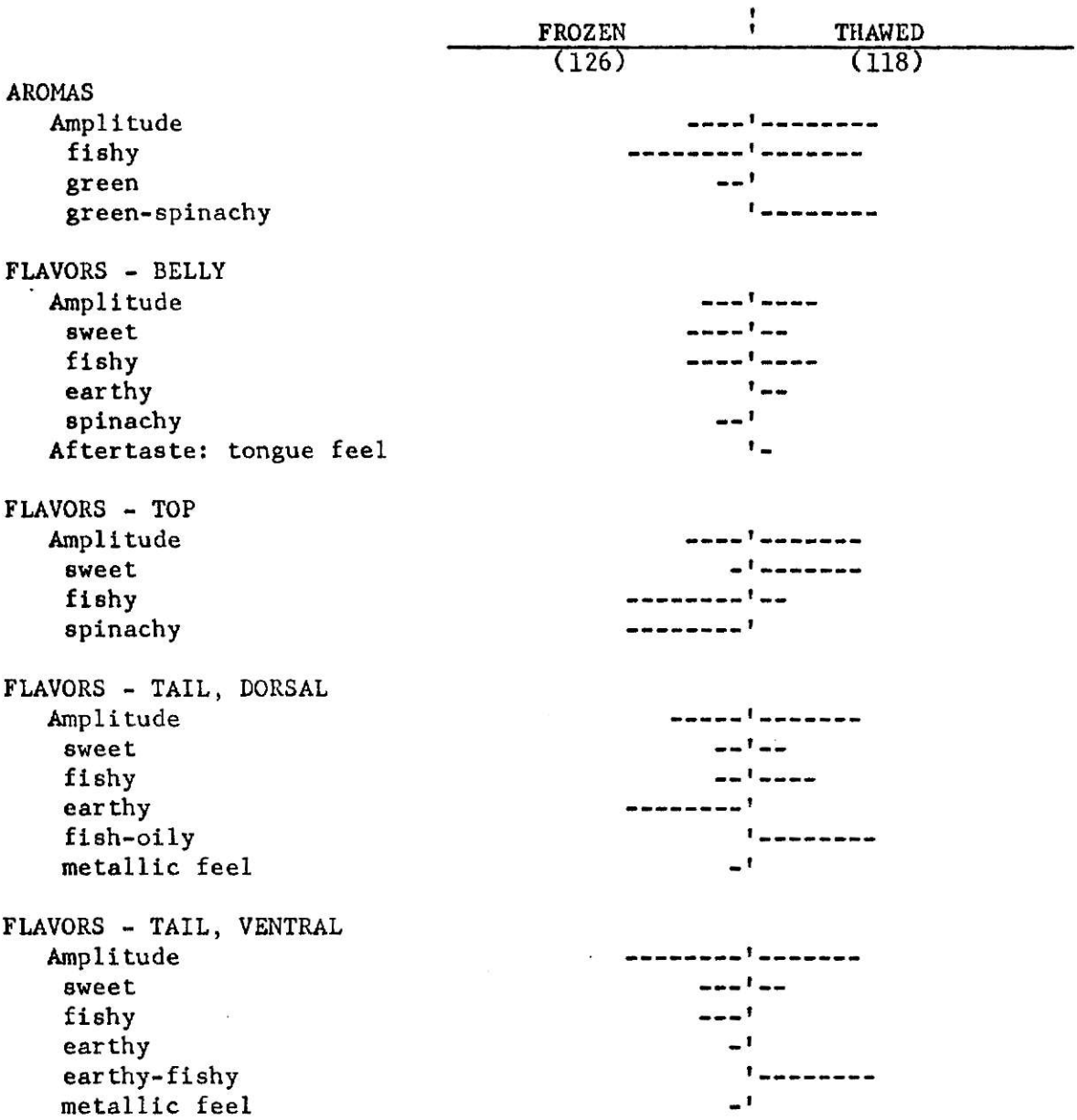


FIGURE 2. (Cont.)

c. Stored 4 weeks

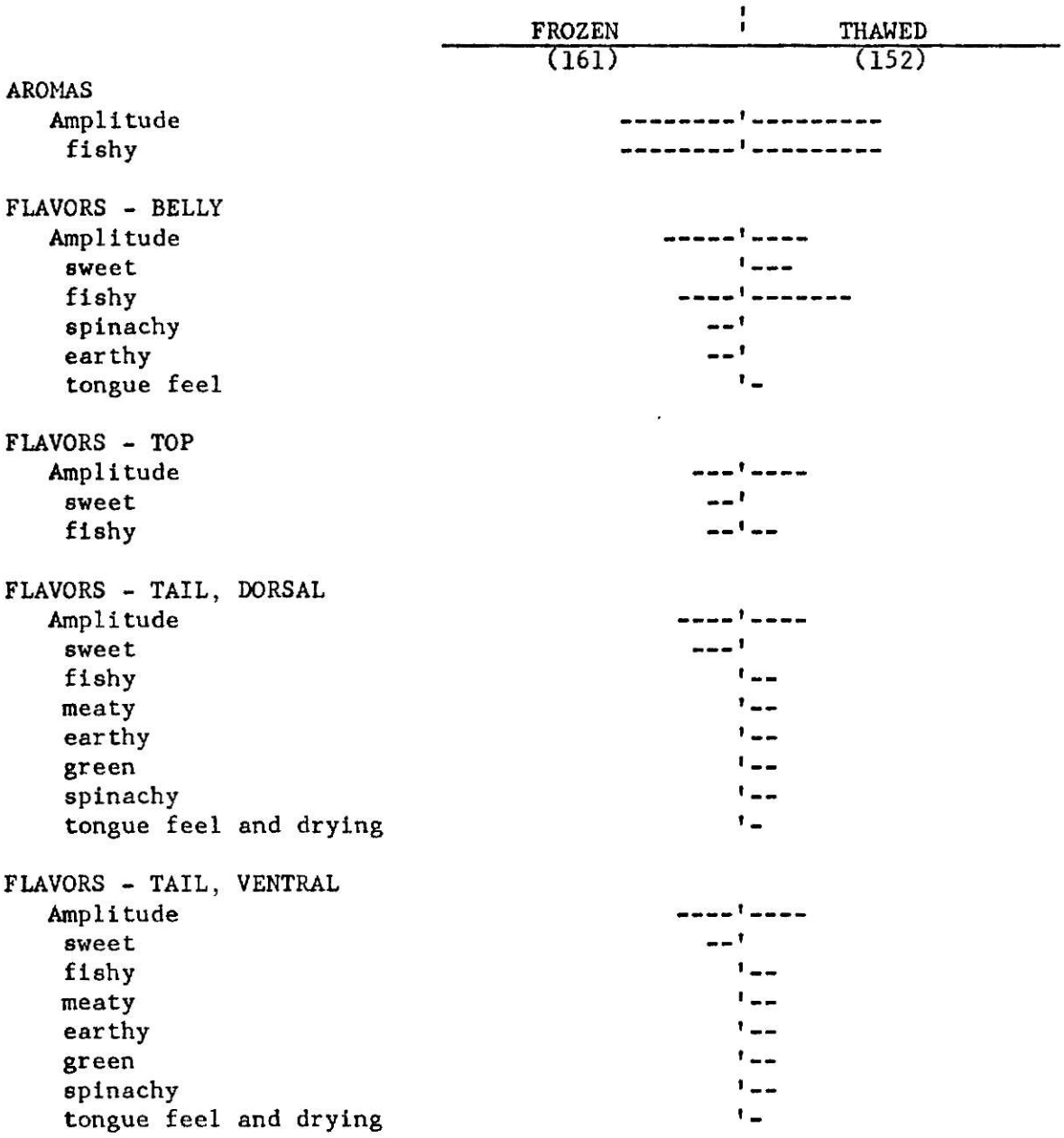


FIGURE 2. (Cont.)

d. Stored 6 weeks

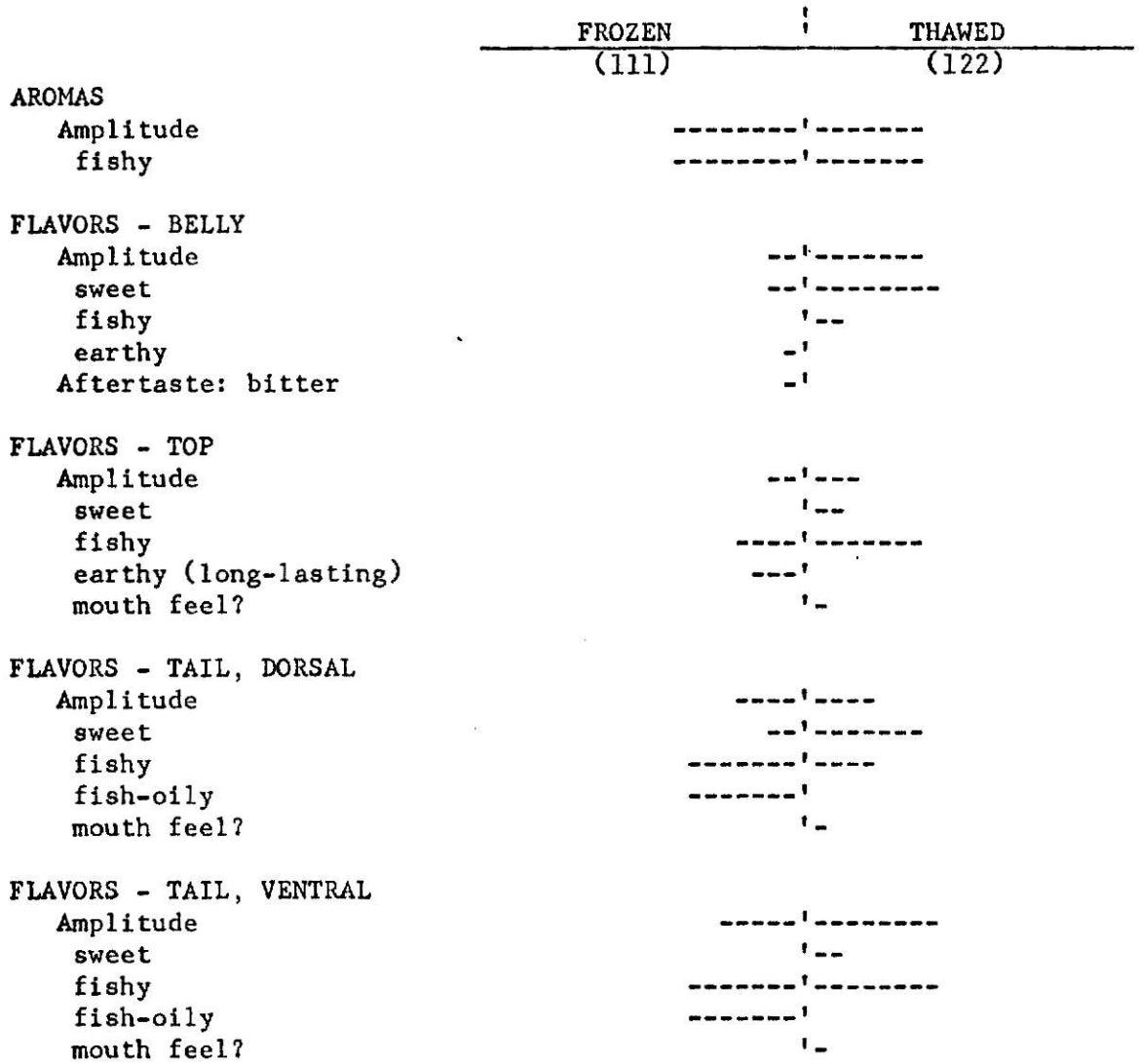


FIGURE 2. (Cont.)

e. Stored 6 weeks + 2 days

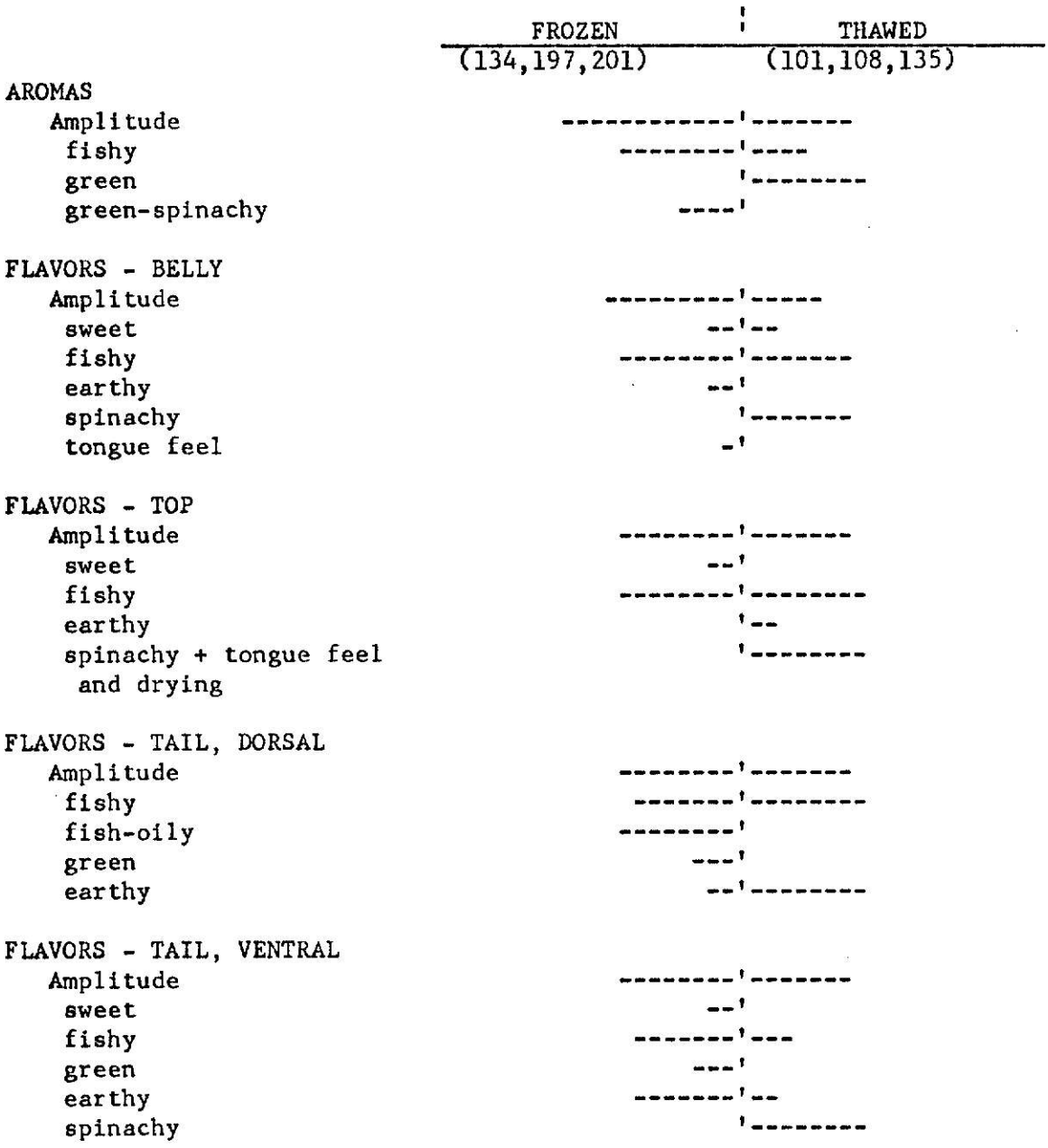


FIGURE 2. (Cont.)

f. Stored 8 weeks

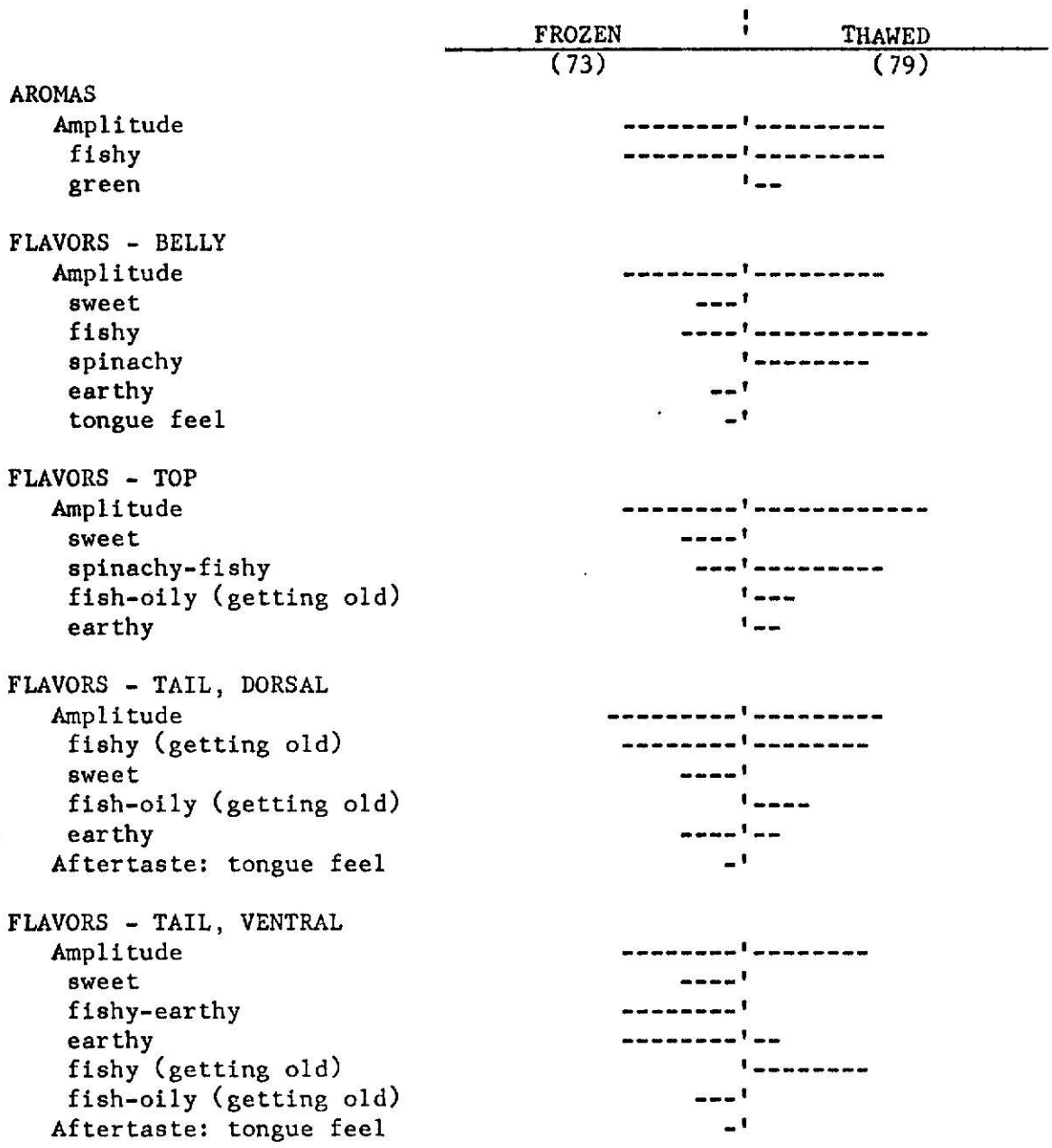


FIGURE 2. (Cont.)

g. Stored 10 weeks

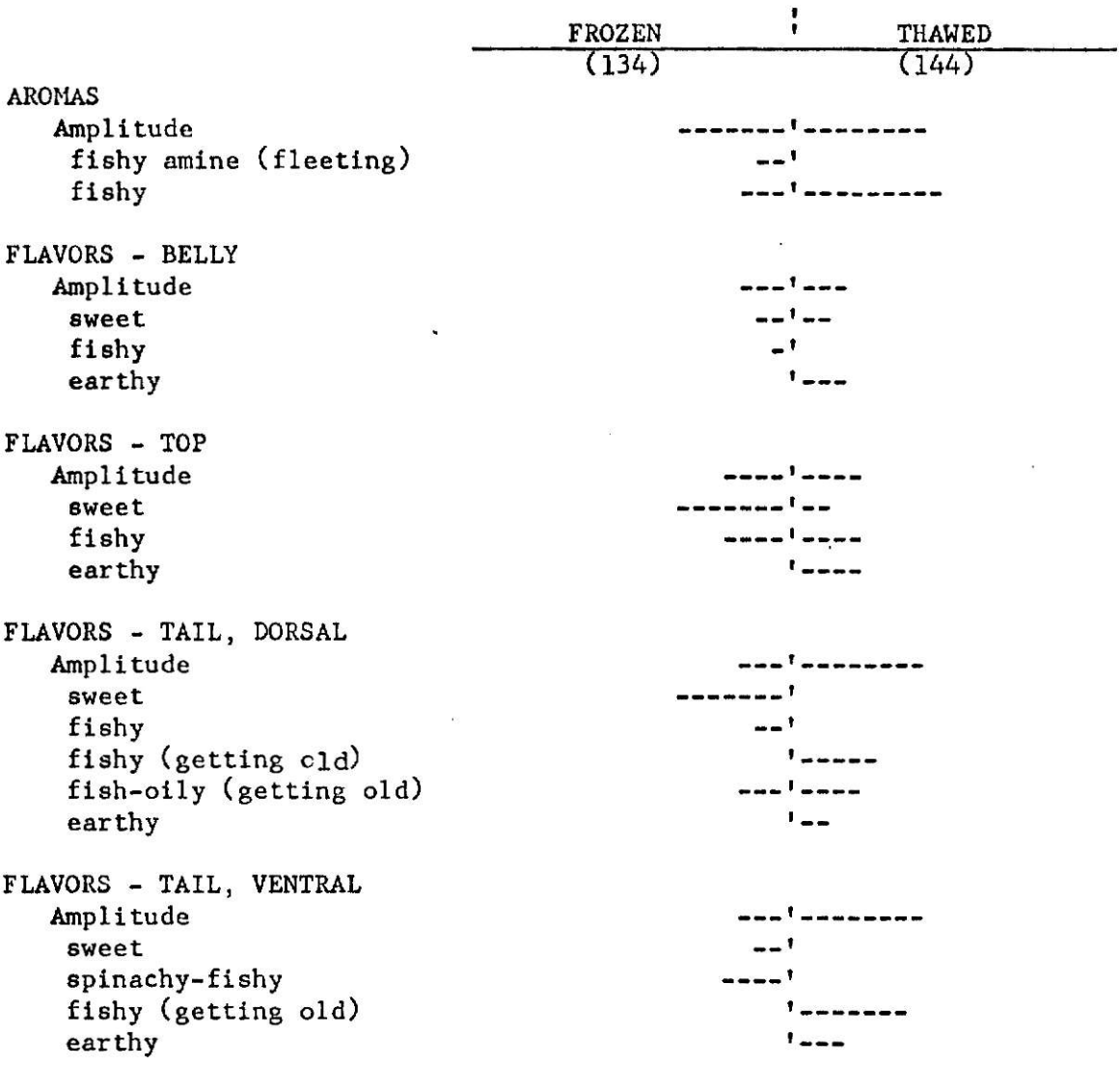


FIGURE 2. (Cont.)

h. Stored 10 weeks + 2 days

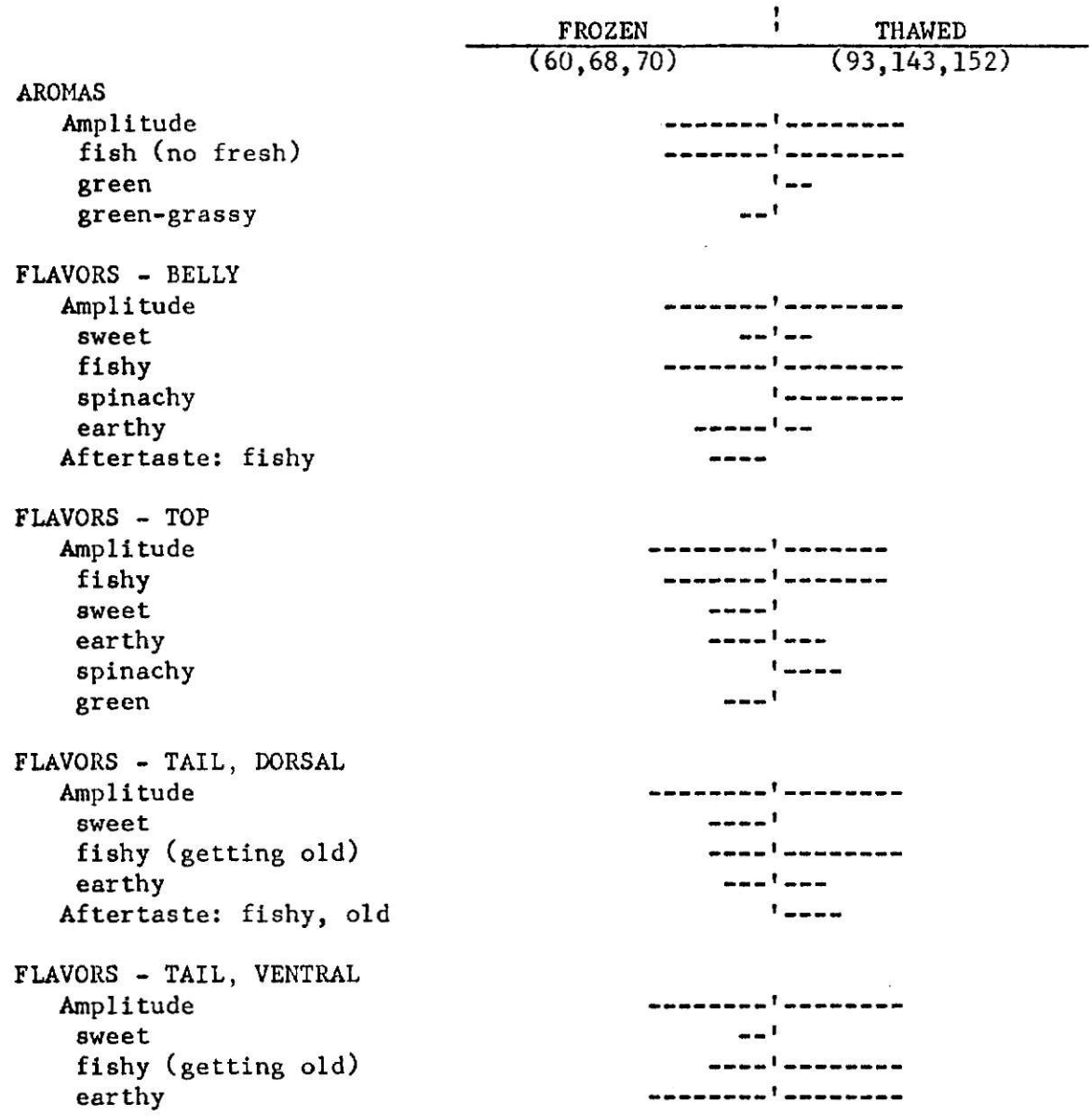


FIGURE 2. (Cont.)

i. Stored 12 weeks

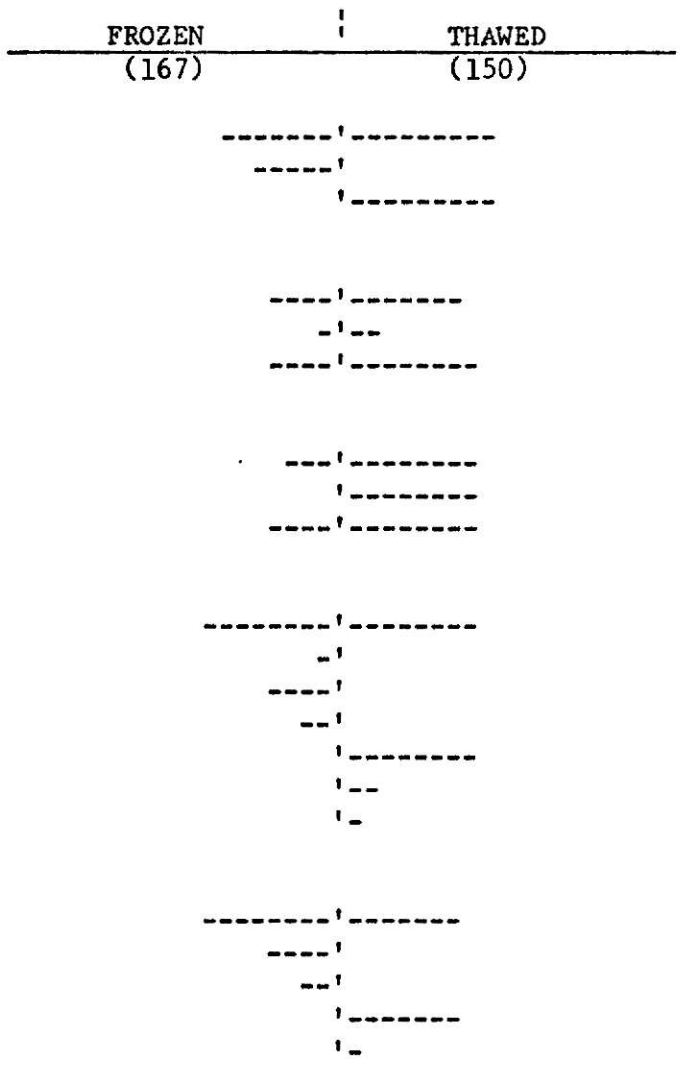


FIGURE 2. (Cont.)

j. Stored 13 weeks

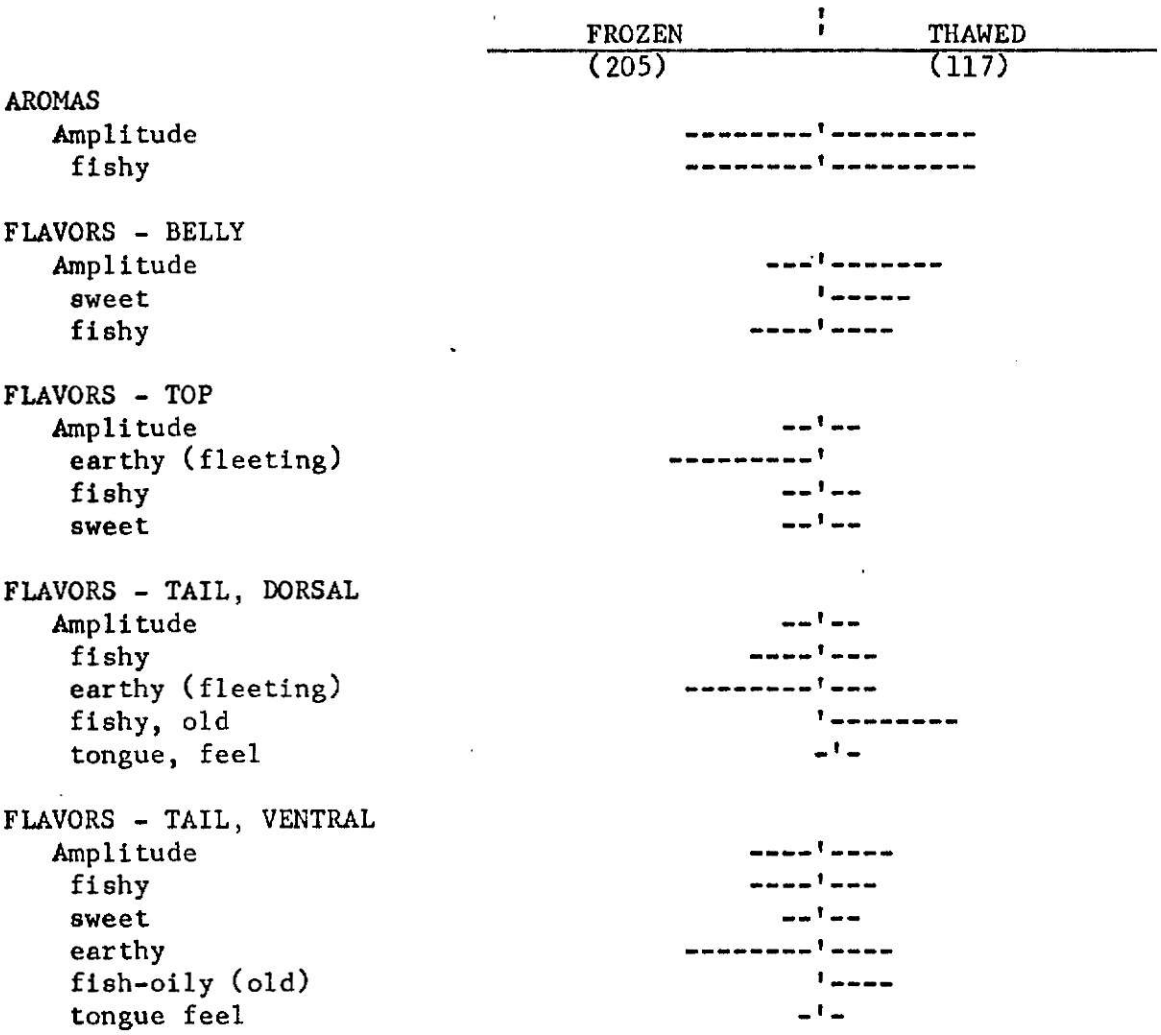


FIGURE 2. (Cont.)

k. Stored 14 weeks

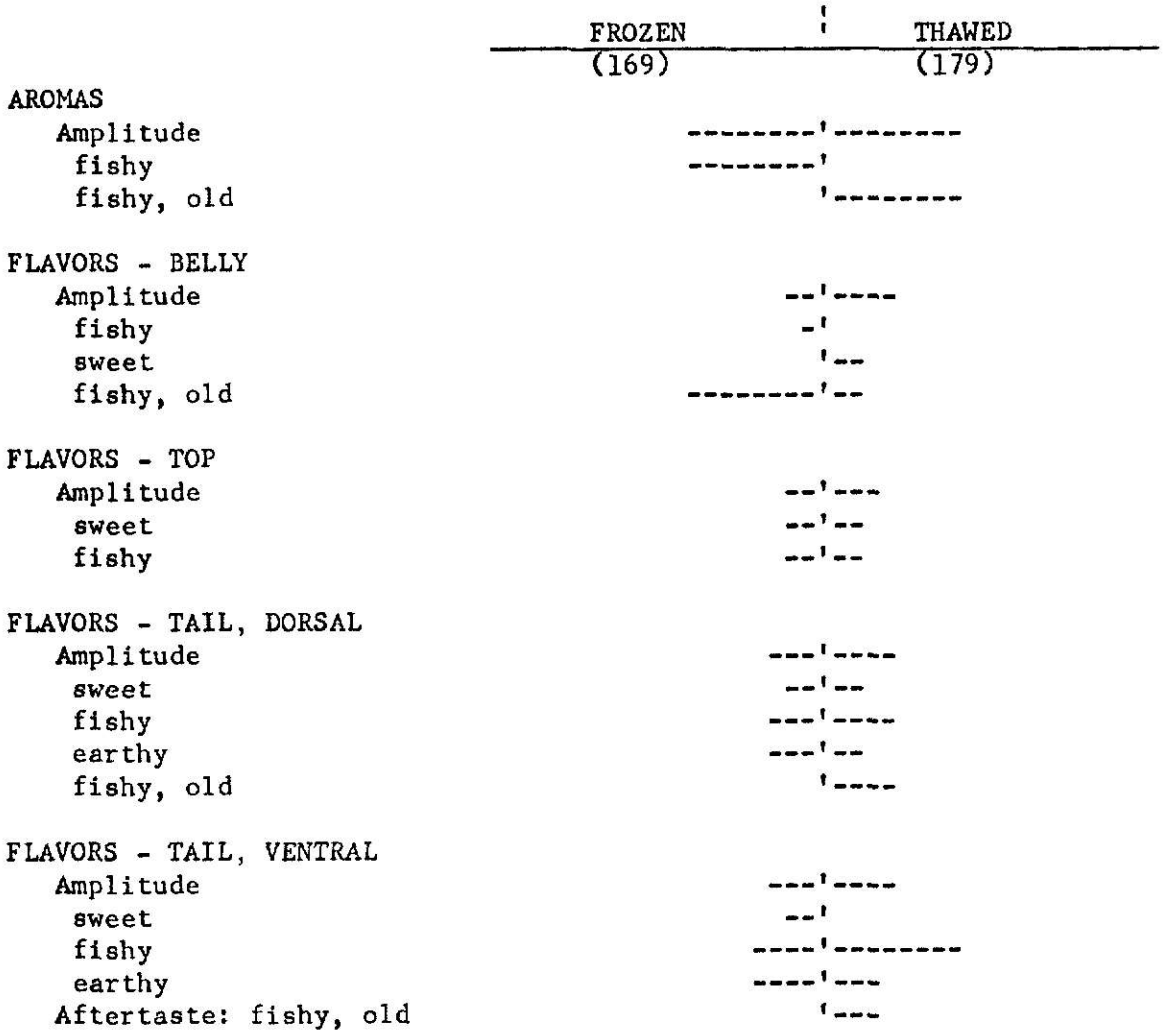


FIGURE 2. (Cont.)

1. Stored 17 weeks

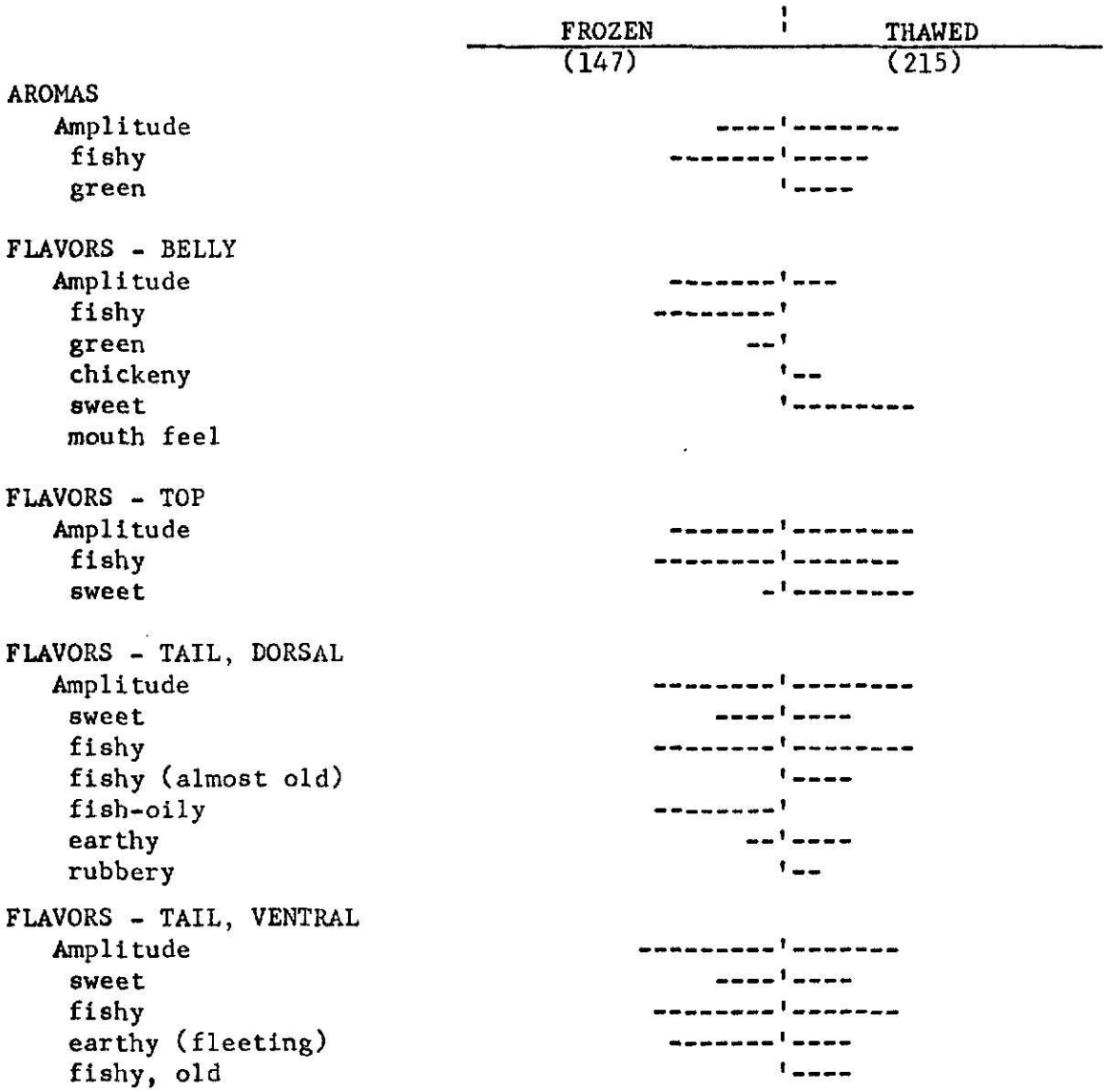


FIGURE 2. (Cont.)

m. Stored 18 weeks

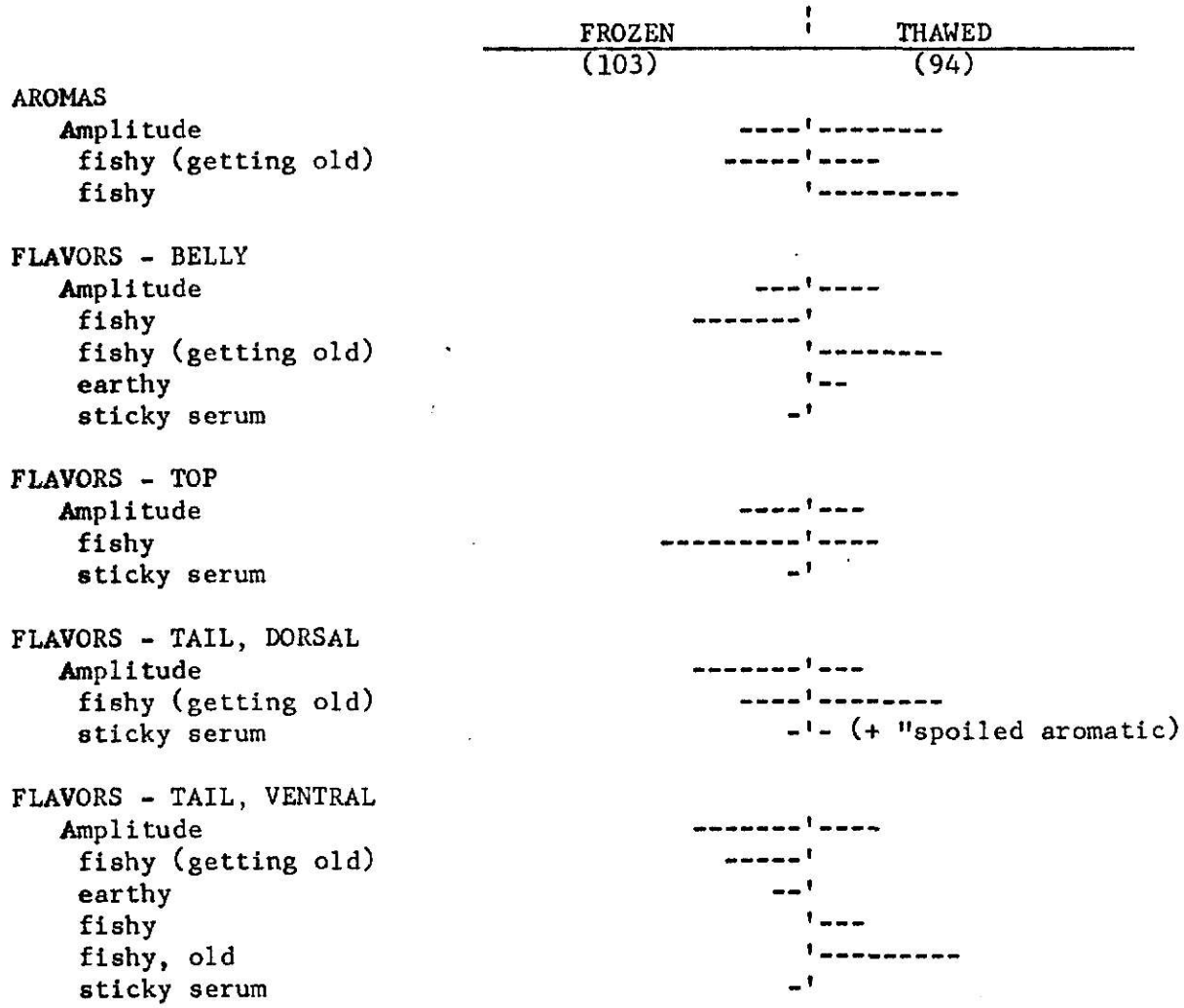


FIGURE 2. (Cont.)

n. Stored 19 weeks

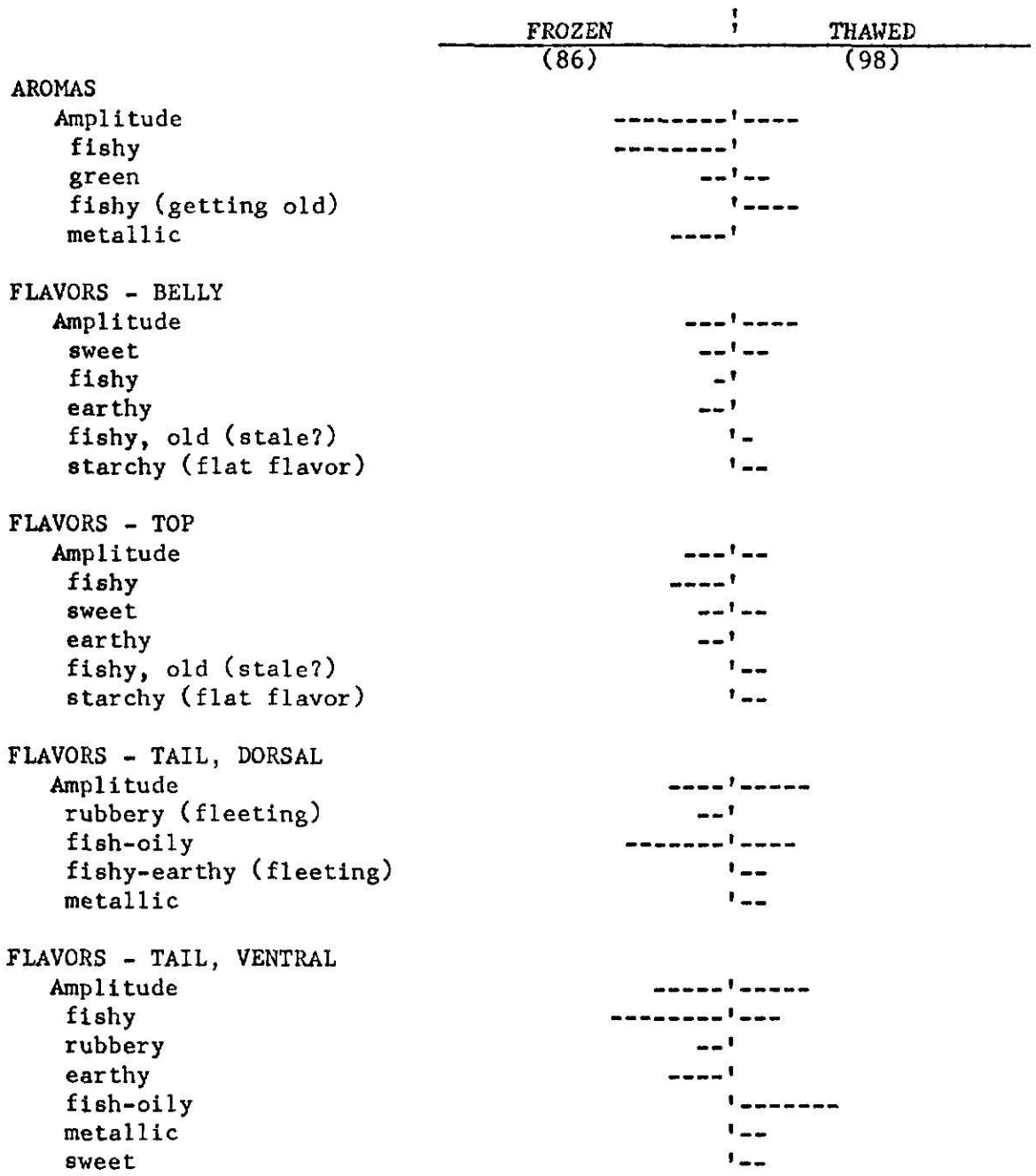
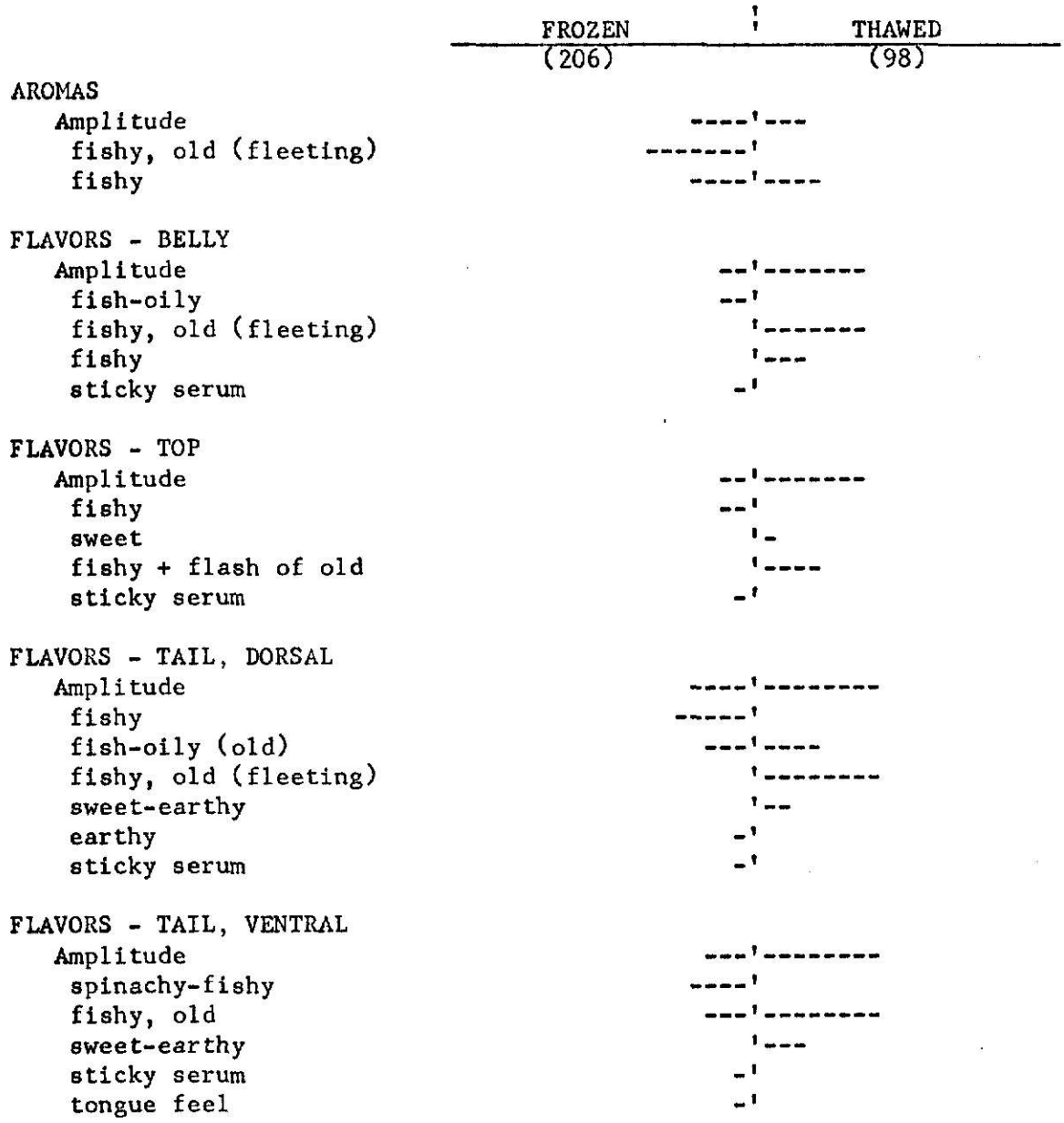


FIGURE 2. (Concluded)

o. Stored 20 weeks



THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

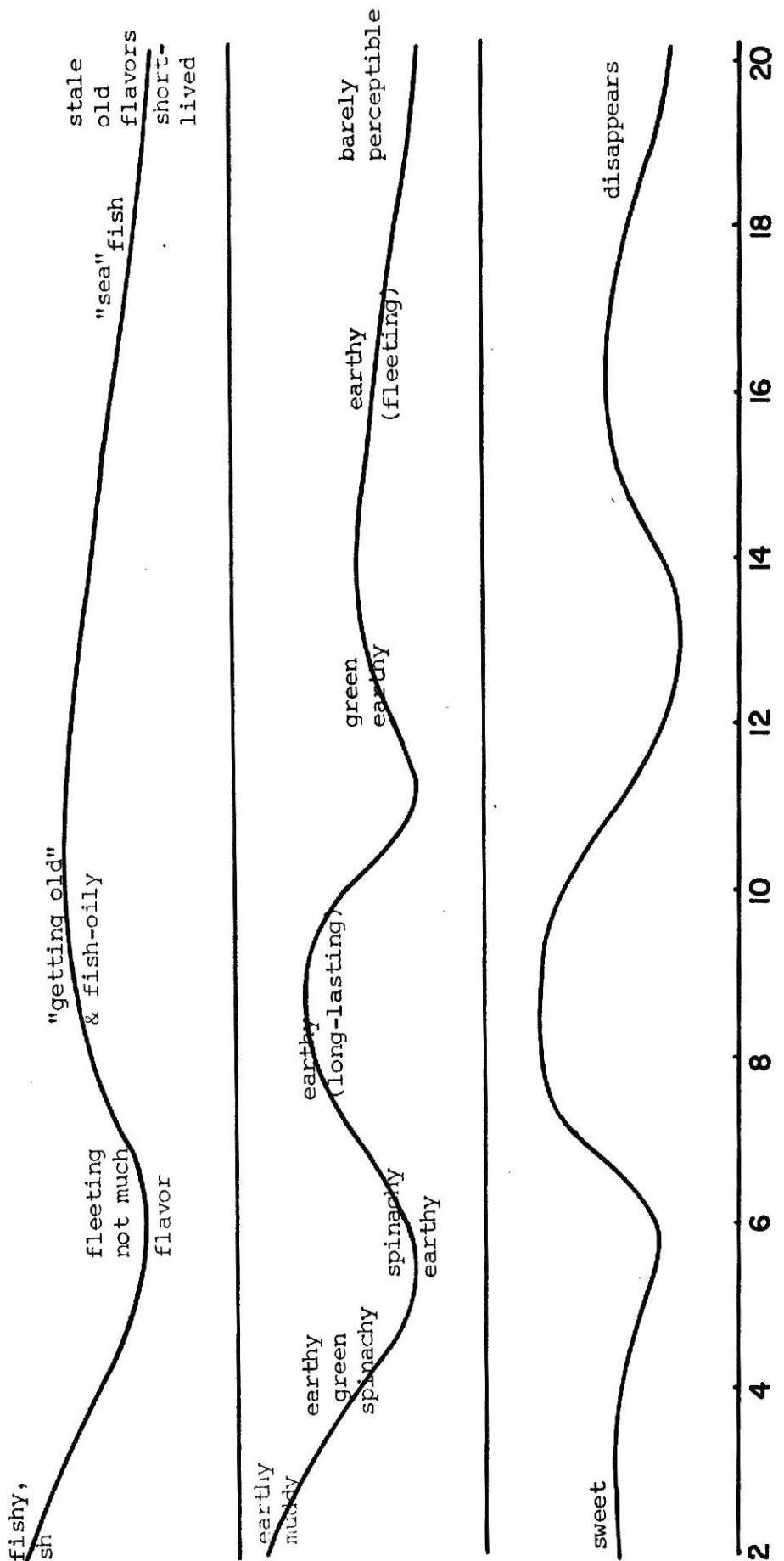


Figure 3a. Changes in the sweet, earthy and fishy character notes of channel catfish cooked from the frozen state, as freezer storage progressed. (The slopes of the lines indicate relative changes in intensities.)

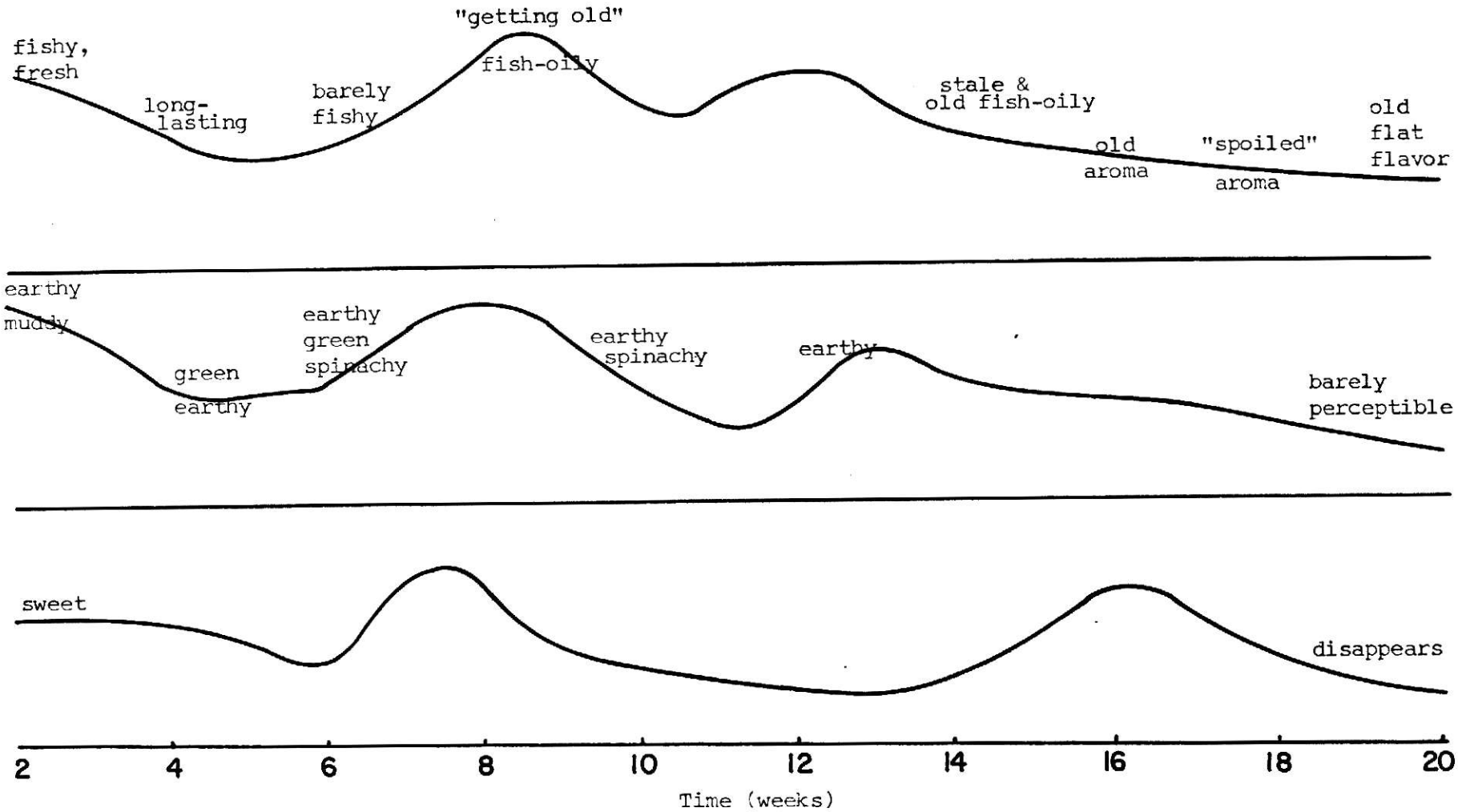


Figure 3b. Changes in the sweet, earthy and fishy character notes of channel catfish cooked from the thawed state, as freezer storage progressed. (The slopes of the lines indicate relative changes in intensities.)

Table 10. Composite profiles of channel catfish fed turkey liver for 19 through 33 days (Phase IV)

19 DAYS		21 DAYS		33 DAYS	
AROMA					
	)(		1+		1
fishy	)(	fishy, fresh	1	chickeny	1
		green	)(		
FLAVOR OF BELLY					
	1-		1		1+
liver aromatic		sweet	)(	chicken aromatic	
earthy-spinachy	)(	chickeny-meaty	1	chickeny	1+
		fishy	1-		
		green, grassy	)(		
FLAVOR OF TOP					
	½		1-		1+
liver aromatic		sweet	)(	chickeny	1-
poultry liver	½	fishy	1-	sweet	)(
earthy-spinachy	)(	chickeny-meaty	1-		
		green	)(		
		fish-oily	)(		
FLAVOR, TAIL, DORSAL					
	)(		1		1
livery-fishy (with old impression)	½	sweet	)(	chickeny	1-
oily	½	fishy	1-	sweet	)(
FLAVOR OF TAIL, VENTRAL					
	½		½		1
fishy	)(	sweet	)(	chicken aromatic	
rubbery aromatic		fishy	1-	chickeny	½
		chickeny-meaty	1-	fish-oily	)(+
		oily	)(+		

Table 11. Composite profiles of channel catfish fed floating feed for 19 through 33 days (Phase IV)

19 DAYS		21 DAYS		33 DAYS	
AROMA					
	)(		1		1-
fishy	)(+	sweet	)(	fishy	1
sweet	)(	fishy	1-		
		green	)(+		
FLAVOR OF BELLY					
	½+		1		½
sweet	½	rotten aromatic		rubbery aromatic	
fishy	)(	sweet	)(	lag	
		fishy	1	fishy	1-
		oily	)(		
		muddy	)(		
FLAVOR OF TOP					
	1-		½+		½
sweet	1-	sweet	)(	feed aromatic	
fishy	0-)(	fishy	)(+	fishy	1-
		green	1		
FLAVOR OF TAIL, DORSAL					
	1		½+		½
fishy-earthy	1	sweet	)(	feed aromatic	
earthy	1	fishy	1	fishy	1-
		muddy	1		
		green grassy	)(+		
		fish-oily	)(		
FLAVOR OF TAIL, VENTRAL					
	1+		1		½
sweet	1-	sweet	)(	feed aromatic	
fishy	0-)(	fishy	1	fishy	1-
meaty	)(	green grassy	)(		
oily	0-)(				

Table 12. Composite profiles of channel catfish fed turkey liver for 33 days (Phase IV)

TREATMENT	FRESHLY CAUGHT		REFRIGERATED OVERNIGHT		REFRIGERATED 2 DAYS	
AROMA	1+		1-		)(	
	fishy	1+	chickeny	1	meaty-chickeny	1+
					chicken fat	1
BELLY	½		1+		1	
	sweet	)(	chicken aromatic		chicken aromatic	
	meaty (fleeting)	1	chickeny	1+	fishy	0-)(
					chickeny	1
TOP	1		1+		½+	
	chicken aromatic (fleeting)		chickeny	1-	chicken aromatic	
	fishy	1-	sweet	)(	sweet	)(
					chickeny	½
TAIL, DORSAL	1-		1		1	
	fishy	1-	chickeny	1-	chickeny	1
	bitter	)(	sweet	)(	liver aromatic (late)	½
TAIL, VENTRAL	1-		1		1	
	"animal" aromatic		chicken aromatic		chicken fat	1
	fishy	1-	chickeny	½	chickeny	1
			fish-oily	)(		

Table 13. Composite profiles of channel catfish fed floating feed for 33 days (Phase IV)

TREATMENT	FRESHLY CAUGHT		REFRIGERATED OVERNIGHT		REFRIGERATED 2 DAYS	
AROMA	1+		1-		)(	
	fishy	1+	fishy	1	fish pond aroma	
	rubbery	1			sulfury (fleeting)	)(
BELLY	)(+		½		)(	
	feed aromatic		rubbery aromatic		rubbery aroma	
	fishy	½	lag		practically nil	
			fishy	1-	fishy	0-)(
TOP	)(+		½		)(+	
	rubbery aromatic	)(	feed aromatic		wet dog-like aroma	
	fishy	½	fishy	)(+	bitter	)(
TAIL, DORSAL						
	)(		½		)(+	
	rubbery aromatic		feed aromatic		wet dog-like aroma	
	fishy	)(	fishy	1-	flat	
	fish-oily	)(			fishy	)(+
TAIL, VENTRAL						
	)(		½		)(+	
	fishy	)(+	feed aromatic		gizzardy ?	
	earthy	)(	fishy	1-	fishy	)(+

PRELIMINARY INVESTIGATIONS ON THE FLAVOR OF FARMED CHANNEL CATFISH (*ICTALURUS PUNCTATUS*)

by

LILIA LAWAS MALIGALIG

B.S., University of the Philippines, 1969

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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Manhattan, Kansas

1971

Four phases of flavor investigations were carried out on three groups (N, R and X) of skinned, dressed channel catfish: an orientation phase, a fasting experiment, a commercial freezer storage study, and a feeding experiment. All samples were cooked by steaming for flavor examination by profile-trained panelists.

X fish taken directly from the pond had earthy and muddy flavors, although N and R fish did not. Several species of algae found in the X fish pond during the fish sampling period may have contributed to these off-flavors. Purging treatment of X fish in an aerated tank with continuous flow of well water affected disappearance of the off-flavors after 18 days.

When all three groups of fish were subjected to a fasting treatment in aerated metal tanks, muddy-flavored lost their off-flavor at a slower rate, probably because of dense tank population.

Flavor of flash-frozen channel catfish continuously changed during 20 weeks of commercial freezer storage. Flavor signs of aging were found after 8 weeks of storage. Fish cooked from the thawed state had older old-fish character than those cooked from the frozen state.

Feeding turkey liver and floating feed produced flavor notes in catfish flesh reminiscent of the respective feeds.