Technology of Mackerel Fishery

Bibliography and Survey of Literature

J.R. Dingle

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ABSTRACT

DINGLE, J. R. 1976. Technology of mackerel fishery — bibliography and survey of literature. Fish. Mar. Serv. Misc. Spec. Publ. 30: 63 p.

Technical and scientific literature up to 1974 pertinent to the use of mackerel as human food has been reviewed. A collection of 184 abstracts, keyed to a list of selected topics, is included.

RÉSUMÉ

DINGLE, J. R. 1976. Technology of mackerel fishery — bibliography and survey of literature. Fish. Mar. Serv. Misc. Spec. Publ. 30: 63 p.

Le présent rapport est une revue de la documentation technique et scientifique publiée jusqu'en 1974 et traitant de l'utilisation du maquereau comme aliment de l'homme. Il comprend 184 résumés renvoyant à une liste de sujets choisis.

CHARACTERISTICS OF MACKEREL MUSCLE

Structure

The edible portion of mackerel flesh consist of two types of muscle rather well differentiated. A band of dark (red-brown) muscle at the lateral line penetrates the adjoining white muscle, forming a wedge extending to the inner body wall. According to Mannan et al. (97), dark muscle amounts to 11.6% of the meat at the thick part of the fillet and about 27% towards the tail.

Lipid Content

It is well known that the fish are relatively lean during the spawning period and become fat later, but surprisingly little quantitative data concerning the fat (lipid) content is available. Sohn et al. (149) reported that mackerel fillets averaged 21.0% lipid over a year; Stansby and Lemon (152) found a minimum of 3.9% (wet basis) in April and a maximum of 19.2% in August for fish caught off New England. Nova Scotia mackerel fillets had 9.1% lipid in early June, rising to 17.9% by October (D. W. Lemon unpublished data). Each month for a year Hardy and Keay (56) sampled Atlantic mackerel off Cornwall, and found a minimum of 6.3% lipid in May and maximum of 23% in December. Both Mannan et al. (97) and Ackman and Eaton (2) measured the lipid contents of various parts of the fillets. The latter found the dark muscle contained about 12% total lipid in spring males, and 9% in females, as against 2–3% for the light flesh in both sexes. Fall mackerel had nearly twice as much fat in the dark muscle and three times as much in the light. The belly flap portion of the fillet was usually the fattest, with a lipid content between 16 and 37%. As is usual with fatty fish, mackerel lipids contain substantial proportions of long-chain fatty acids, many highly unsaturated (Hardy and Keay 56; Ackman and Eaton 2); there is, therefore, a strong tendency to rancidity, and this is probably the principal difficulty in the storage of mackerel.

Protein Composition

According to Braekkan and Boge (21), amino acid composition of mackerel muscle protein is similar to other common food fishes, except the content of histidine is about twice as high (4.5%). Cystine and possibly tryptophan were considered limiting among the essential amino acids. Matsuura et al. (100) found little difference in amino acid composition of the protein between the light and dark muscle of *Scomber japonicus*.

Nitrogen Extractives

The trimethylamine oxide content of the muscle was reported by Dyer (40) to be in the range 31–54 mg N/100 g of muscle, a relatively low value among fishes. Mannan et al. (97) found a range of 27–55 mg N/100 g for different parts of the muscle, with the dark portion having the highest level. This is also the case with Japanese mackerel; Tokunaga (167) found about 27 mg TMAO–N/100 g in the dark muscle, and only 15 mg N/100 g in the light portion. Mackerel muscle is notable for having a large proportion of free histidine among other extractable nitrogen compounds. Fraser et al. (46) found 400–600 mg histidine/100 g in the light muscle, but only about 100 mg/100 g in the dark muscle of 23 samples of Atlantic mackerel taken in June and July. Lukton and Olcott (89) and Sakaguchi and Shimizu (129;130) reported even higher values (500–800 mg/100 g) for *S. japonicus.* Histidine can be decarboxylated to histamine by certain bacteria, and this has been implicated in occasional cases of food poisoning traced to tuna and mackerel.

Vitamins

In a review of the vitamins of fish, Grangaud (52) pointed out that the flesh of fatty fish such as mackerel is a particularly rich source of vitamins A, D, and E, and that the amounts of B_1, B_2, nicotinic acid, pyridoxine, and pantothenic acid are about the same as in meat. Animal protein factor is also present in the fish, but folic acid may be lower than in meat. Other reported data on vitamin contents (per 100 g of mackerel flesh) are given in the table below.

			S. scombrus[3]	
	S. scombrus[1]	*S. japonicus*[2]	Ordinary muscle	Red muscle
B_{12}	4.85γ	4.4γ	1.5γ	11γ
Nicotinic acid	7.62 mg	9.2 mg	10.7 mg	9.7 mg
Pantothenic acid	–	–	0.38 mg	3.0 mg
Riboflavin (B_2)	251γ	254γ	160γ	1380γ
Thiamin (B_1)	–	108γ	20γ	370γ
α-Tocopherol (E)	–	–	–	1.52 mg[4]

[1] Teeri et al. (165).
[2] Komata et al. (82).
[3] Braekkan (20).
[4] Ackman and Cormier (1).

This data tends to confirm the resemblance of Atlantic and Japanese mackerels, but also shows that red muscle contains much higher levels of most of the vitamins than are found in lighter muscle (Braekkan 20).

INTRODUCTION

The mackerel fishery in eastern Canada has remained virtually unchanged for generations, not only in method of catch but particularly in utilization. Only part of the catch is used as human food, and most is consumed shortly after landing as "fresh" fish. The quality of the mackerel, either fresh or marketed in other forms (canned and frozen), often leaves something to be desired. As part of the overall effort in encouraging better utilization of the available resources, the expanded use of mackerel for food is being advocated.

As a preliminary step in an effort to improve mackerel as food in its present forms, or to develop new forms, we have undertaken a review of pertinent information found in technical and scientific literature. Emphasis has been placed on the use of the fish as human food, and so information regarding fish meal has been ignored. The approach of including the abstracts with the references, in addition to the review, was taken to provide more detailed information for the reader.

GENERAL

To the earliest European settlers of the eastern shores of North America and to those who followed them, Atlantic mackerel has been a welcome food when it reappeared each year in their waters. In any one locality, however, the fish are abundant for only a few weeks, and disappear altogether from the inshore areas in winter months. However, success of the fishery is apt to vary widely from year to year. The effects of this feast or famine characteristic might be eased somewhat if it were possible to store the fish taken in time of glut for future use, but mackerel is a fatty fish with delicate flesh and, therefore, subject to rapid deterioration if mishandled.

The Atlantic mackerel (*Scomber scombrus*) is closely related to the Spanish or chub mackerel (*S. colias*) of more southern waters, and the Japanese mackerel (*S. japonicus*) of the Pacific Ocean. Some authorities hold that the latter two species are identical, and the only important biological difference between them and the Atlantic mackerel seems to be that *S. scombrus* lacks the airbladder or swimbladder possessed by its relatives. Much of the technical literature concerns these relatives, and this has been taken into account because, in all likelihood, the information is pertinent to Atlantic mackerel as well.

Ecology and fishery statistics of Atlantic mackerel have been reviewed by MacKay (93) and Hoy and Clark (68). The mackerel is a schooling pelagic fish that inhabits the waters of the continental shelf on both sides of the North Atlantic Ocean, and is found in the Mediterranean and Black seas as well. The western Atlantic population is divided into northern and southern sections that migrate from winter quarters along the outer shelf. The northern group spawns off Nova Scotia and in the Gulf of St. Lawrence and the southern group spawns principally off New Jersey. There is some mingling of the groups in the Gulf of Maine during the migration, but the "Canadian" contingent separates and proceeds northward, mostly to the Gulf of St. Lawrence, although some groups appear to remain near certain bays of Nova Scotia. Migrating groups are roughly homogeneous as to size of fish, probably because size is related to swimming speed, so that the larger faster-swimming fish arrive first, followed by the smaller "tinkers." It is because of this migration pattern that the mackerel fishery in a given Canadian area is apt to be very good for a few weeks and then decrease as the schools pass through, and that the time of abundance varies from place to place. The migrations are probably triggered by water temperature, and 8 C appears to be critical. Until recent years, most of the catch was taken in or near territorial waters during the migrations, but catches are now taken over the outer parts of the continental shelf during the winter months, particularly by the Russian fleet.

Size of the mackerel population, and hence success of the fishery, has historically been very unstable (Hoy and Clark 68), but it is unlikely that dramatic failures experienced in some years can be entirely ascribed to overfishing in previous seasons. Large fluctuations are thought to be caused mostly by the degree of survival of eggs and young-of-the-year, which, besides predation, are subject for a time to the vagaries of the weather. Adverse winds, for example, may push them into zones of lethal temperatures or where food is scarce.

In the years since the reports of MacKay (93) and Hoy and Clark (68), fishing for Atlantic mackerel by the USSR, Poland, and East Germany has been greatly intensified, and the USSR now rivals Norway for first place. Canada's share of the world catch of 802,000 metric tons(t) in 1971 was only 1.86% (15,000 t). Of Norway's catch of more than 200,000 t, about 90% was used for production of meal rather than for human food. Approximately 35% of Canada's production was sold as fresh or frozen round or dressed fish, but much of the frozen product was fed to zoo animals in the United States or used as bait by domestic and foreign fishermen. The remaining fish were pickled (6.6%), canned (8.7%), or reduced to meal. By contrast, Japan *exported* in 1972, 184,453 t of canned Pacific mackerel, or 14.7% of its total catch. (Sources: Canada Department of Industry, Trade and Commerce, *A Review of Selected Mackerel Markets*, 1973; Department of the Environment Annual Statistical Review of Canadian Fisheries, Vol. 5).

Seno (133) recently published a succinct review of the mackerel fishery, the processing characteristics of the fish (*Scomber japonicus*), and procedures used for preparing various products from it, particularly those popular in Japan.

HANDLING OF FRESH MACKEREL

In a 1941 report (much of it still valid today) Stansby and Lemon (152) reviewed the mackerel fishery and methods of handling the fish for sale as an unfrozen product in the United States. They pointed out that the flesh of mackerel is rather soft, and the presence of the relatively large amount of oil makes it even more delicate, so special care must be exercised to avoid bruising the flesh or damaging other tissues. This is particularly true when the fish are full of feed, because then the digestive enzymes are very active and begin to attack the walls of the digestive tract soon after the fish dies. This makes the tissues even more susceptible to rupture by rough handling, leading in turn to attack of the flesh by the released enzymes. For a time after death, however, the fish pass through rigor mortis, and while in full rigor very little decomposition takes place, either by visceral enzymes or by surface bacteria. After passage of rigor the skin can no longer act as a protective barrier against bacteria, which can then penetrate the flesh and cause deterioration.

Once rigor has passed it is highly desirable that the fish be eviscerated and then stored in ice. Nickerson et al. (108) found that enzymic action (autolysis) was greater in uneviscerated mackerel than in fillets when both were stored in ice. Stansby and Lemon (152) showed by organoleptic testing that while round fish stored in ice were rejected after only 4–7 days, fish gutted before icing were acceptable for up to 17 days. They emphasized that the fish should be gutted on board the catching vessel, or as soon as landed, to avoid losing much of the value of evisceration. On the other hand, they found that wrapped fillets stored in ice did not keep better than round fish similarly stored, perhaps because of the greater surface available for oxidation or greater bacterial contamination during handling. Fraser et al. (46) also found that mackerel, gutted, iced, and packed in polyethylene bags within about 2 h of catching, were rejected by taste panels after 17 days in ice, but that if the fish were left at 13–20 C for 7 h before processing and storing in ice the storage life was reduced to 12 days. They further pointed out that the decrease in taste scores closely paralleled the loss of the flavor enhancer, inosine monophosphate, that is formed in the muscle during the early postmortem stages, and subsequently degraded to hypoxanthine. A progressive loss of "fresh mackerel" flavor leading to tastelessness occurred before the appearance of offensive bacterial spoilage odors and flavors, which eventually caused rejection by the taste panel.

The possibility of using additives to prolong the keeping time near 0 C has been the subject of several investigations. Noguchi and Bito (112) reported that when mackerel were held in ice acidified to pH 2.5–3.5 the start of putrefaction was delayed about 10 h beyond the time for fish stored in ordinary ice. Tsuchiya et al. (174) found that storing beheaded and gutted mackerel in a 1% brine containing 0.01% butyrated hydroxyanisole was better than immersion in plain 1% brine, in ice water, or in ice mixed with 1% salt, but all were better than storage in ice alone. Preservation time was 3–5 days longer than ice alone when round mackerel were held in ice containing 33–100 ppm of furantoin, or in plain ice after being dipped in a 50–100 ppm solution of furantoin. Fillets kept better after dipping in a solution of furantoin and citric acid than in a solution of furantoin alone (Tokunaga and Nakamura 168). Tomiyama and Yone (171) reported that mackerel immersed for 6–7 days in ice and sea water containing 3–6 ppm chlortetracycline (CTC) remained acceptable for a further 7 days at 3–7 C, compared with 5 days for the control group. The CTC residues in the muscle and skin were 0.05–0.09 ppm and 0.6–1.3 ppm, respectively, and in the presence of the CTC, the formation of histamine in the muscle was greatly inhibited. In view of the prevailing opinion against the use of antibiotics in foodstuffs, however, this work is now largely of academic interest only.

It was formerly a common practice to ship round mackerel packed in ice in barrels, with enough sea water to "float" the fish to protect them from being crushed by the weight of the ice and each other. Stansby and Lemon (152) showed, however, that such fish had a storage life of only 1–2 days. Under these conditions, anaerobic spoilage can lead to formation of H_2S that becomes trapped under the skin and is particularly offensive when the fish are first cut. Such "floated" storage resembles the more modern refrigerated seawater storage, but in the older method, as there was no provision for mixing, temperature stratification could occur. The lower layer would then become appreciably warmer, perhaps as high as 4 C, the temperature at which the density of water is a maximum, and spoilage would proceed rapidly.

Recent experiments (Lemon and Regier 83) on holding round mackerel at –1 C in circulated refrigerated sea water (RSW) have shown that the fish retained a good inspection grade after 8 days, while similar fish kept in ice were rejected. Some off-odors were noticeable in the RSW-held fish, but these largely disappeared on cooking. When the RSW was saturated with CO_2, the pH was lowered from 6.4–6.7 to 5.4–5.8, but off-odors persisted, so that bacterial activity in the water did not seem to be greatly affected. The pH of the fish flesh was reduced by only 0.1–0.2 units. No significant difference could be detected in the quality of the fish kept in the two RSW systems. Oxidative changes in the lipids, however, were significantly retarded in the fish held in either RSW system compared with iced fish. A distinct disadvantage of the RSW–CO_2 system was that CO_2 diffused into the fish flesh, and was released in subsequent cooking, causing considerable difficulties during canning operations.

Mackerel that have eaten "red feed" (*Calanus finmarchius*) are particularly prone to spoilage because of an extremely rapid autolysis (self-digestion), and an evolution of H_2S in the flesh. Such mackerel will clear the feed if left in a trap for 24–48 h, thus eliminating the problem (Stansby and Lemon 152).

Fish of the mackerel–tuna group have occasionally been implicated in gastrointestinal upsets or "food-poisoning" (Shewan and Liston 138; Kawabata et al. 74–6). A discussion, chiefly medical, of this problem is given by Halstead and Courville (54). The poisoning appears to be due to the action of certain marine bacteria in producing histamine from the histidine normally present in relatively large amounts in these fish. Histamine does not, however, seem to be the only necessary component in the toxin causing the illness (Merson et al. 102), and in any case, properly handled fish are unlikely to become poisonous until long after they have become unpleasant to the taste from other causes.

Hess (61) recommended that mackerel destined for canning be frozen in the round until the processors were able to deal with them and a similar procedure might be used for holding fish intended for other uses. Unfortunately, few if any of the small ports on the Canadian east coast where mackerel are landed from the inshore fishery possess suitable freezer facilities, so it would be necessary to transport the fish for some distance before freezing. In addition, the fish are frequently landed at these ports in small open boats without any refrigeration. Consequently, it is essential that they at least be adequately iced immediately upon landing and before being taken away for freezing. A better alternative, except perhaps for expense, would be the use of trucks equipped with refrigerated seawater tanks. A similar problem arises with the offshore mackerel taken by trawlers. As the storage life of iced round mackerel is very short, and the chances of achieving a really satisfactory dressing of the fish under sea conditions are not good, it seems likely that the use of refrigerated sea-water systems, or of freezing trawlers, or factory ships will have to be seriously considered. A mixture of sea water and ice in the form of a slush can be used to provide the refrigeration on board the vessels and the mechanical refrigeration equipment left on the dock.

FREEZING

Although frozen storage is currently used for the preservation of mackerel fillets as well as round fish (used in Canada mostly as bait), the literature contains little useful data concerning the shelf life under various conditions. Pottinger (125) found that mackerel fillets, wrapped in moisture-vapor-proof cellophane, retained flavor and texture acceptable to a taste panel for 4 mo at –23 and –18 C, and for 2 mo at –9 C. Storage at temperatures fluctuating between –23 and –18 C did not seem to affect the storage life, while those samples fluctuating between –18 and –9 C deteriorated at about the average of the rates of samples stored constantly at –18 and –9 C. Loosely wrapped fish deteriorated much more rapidly than tightly wrapped samples. The taste panel scores roughly correlated with measurements of volatile acids, indicating that developing rancidity was a principal factor in loss of palatability. The amount of thaw-drip was only 3–4%, and did not vary much with storage time or temperature. Botalla et al. (18) also reported that mackerel fillets wrapped in Cryovac film remained in good condition for 4 mo at –18 C.

Nishimoto (110) found that Japanese mackerel, frozen round, became unpalatable after 2–3 mo at –10 C, and after 4 mo at –20 C. Glazing the fish prolonged the shelf life somewhat. In addition to the development of rancidity, there was a progressive denaturation of the structural proteins, which was accompanied by an increasing amount of drip where the fish were thawed (up to 12.5% after 6 mo at –10 C). It also appeared that the protein denaturation could be correlated with the formation of fatty acids and oxidation products from the deteriorating lipids. On the other hand, Dingle and Hines (33) found that in minced flesh of Atlantic mackerel stored for 35 days at –5 C there was little loss of protein solubility, even though free fatty acids increased rapidly to more than 800 mg/100 g of flesh; TBA values were, however, relatively low, indicating 1.2 μmol malonaldehyde/100 g of fish.

RANCIDITY PROBLEM

While further investigation may confirm that protein denaturation in frozen stored mackerel is significant, the deterioration of the lipids leading to rancidity is undoubtedly the more important form of spoilage from the point of view of consumer acceptance, not only in the frozen fish, but in the unfrozen as well. It has long been known that the fatty layer next to the skin becomes rancid much sooner than the deeper layers; in fact, some buyers have been known to bite into the back of the raw fish, and finding no rancid flavor there, are assured that the remainder of the flesh would be satisfactory. It is natural to expect that the lipids near the surface of the fish, and thus more readily accessible to atmospheric oxygen, should be the first to spoil. Ke et al. (79), however, found some evidence suggesting that the lipids associated with the skin are much more sensitive to oxidation in frozen storage than the fats deeper in the flesh, and suggested that the fish should be skinned, mechanically or chemically, before being stored.

The composition of the lipids was studied by Ackman and Eaton (2) who measured the proportions of triglycerides and phospholipids in the light and dark flesh and the liver of Atlantic mackerel, and also presented a detailed analysis of the fatty acid composition of the total lipids. The phospholipid fractions from several tissues of the Japanese mackerel were investigated in greater detail by Tsuyuki et al. (176).

Changes in the lipids during storage have been the subject of several investigations. Ono (120) reported that the hydrolysis of the fats in mackerel at –13 C was due to the action of the enzyme lipase, acting mainly on the unsaturated glycerides, and that phosphatides may also be hydrolyzed by a lipolytic enzyme. Ono found that freezing in air or brine, or glazing the fish had no effect on the chemical changes in the fat. Viviani et al. (178) found that for spring mackerel with low total lipid content, free fatty acids formed during frozen storage represented only 59% of the total fatty acids, and appeared to be derived from both neutral fats and phospholipids. For fall mackerel with high lipid content, the free fatty acids represented only 5% of the total fatty acids, and appeared to be derived from neutral fats. From their study of minced flesh stored at 20 C, Takama et al. (156) concluded that lipid degradation was due to hydrolysis and oxidation. Mel'nikova and Khalina (101) found that these reactions occurred vigorously in mackerel stored at –8 to –10 C, but not below –40 C.

Several procedures have been used commercially to suppress lipid degradation, among which glazing and close wrapping in suitable films are the commonest. Unless precautions are taken, the glazing may evaporate in the freezer, exposing the fish to oxidation (Nishimoto 110). Stoloff et al. (153) found that glazes thickened with carageenin and containing antioxidants such as gallic acid, ascorbic acid, or nordihydroguaiaretic acid extended the storage life of mackerel fillets from 3 mo to about 8 mo under the conditions they used. A Norwegian process in which the fish are block frozen in an alginate jelly is also claimed to retard rancidity and to reduce freezing time by up to 25% (Helgerud 59; Olsen 119). Even when vacuum packing in bags of polyethylene-cellulose film is used, treatment with antioxidants can be of further advantage. Bauernfeind et al. (15) showed that rancidity could be retarded in mackerel fillets by a dip in ascorbic acid solution before wrapping in cellophane or Pliofilm for storage at –11 to –18 C. Liljemark (84) found that vacuum packing combined with enzymic oxygen uptake (addition of glucose and glucose oxidase-catalase) was as effective at –20 C as vacuum packing alone at –30 C. Finally, Fiedler (44) reported that the rather quaint treatment of Atlantic mackerel with a water extract of oat flour caused them to be "of superior quality to untreated fish after 6 months storage." It is probable the extract contained a salt of phytic acid that would chelate with traces of metal ions, particularly iron, in the fish tissues, which are known to catalyze the formation of rancid flavor from the lipids.

CANNING

In preparing Atlantic mackerel for salmon-style canning, it has been a common practice to behead the fish, split them down the back, cut out the backbone along with fins and tails, and remove the viscera including the kidney tissue along the backbone. After rinsing with water they are usually soaked in brine (e.g., 12 min in saturated brine, Hess 62); this treatment removes slime and blood from the flesh and imparts a desirable salty flavor. The unskinned fish are then cut into can lengths and packed tightly into the cans for processing. For this, Hess (62) specified exhausting for 8 min in a boiling water bath or steam chest, and retorting for 80 min at 115 C. Dewar and Swansburg (31) tested a procedure for canning mackerel without the preliminary cooking before retorting. It was necessary to use some form of vacuum-sealing equipment, and care had to be taken in packing to ensure sufficient head space and absence of air pockets. The quality appeared to be slightly inferior to normal pack, for an experienced fish grader may identify ". . . . a slight objectionable odour and flavour. . ."

Mackerel, like salmon, is normally canned without skinning, but the presence of the dark skin may be objectionable to some. The skin, being thin and rather delicate, is difficult to remove by knife, but Lopez-Benito (87) used sodium hydroxide to remove it. Immersion of whole or dressed fish in a 2% NaOH bath at 60–80 C for 2 min followed by washing with water and neutralizing with citric acid gave "fair" results. A taste panel could detect practically no difference between hand-skinned canned mackerel and that skinned by the alkaline treatment. Further tests of this type of procedure should be made.

It is not possible to prepare fish products of superior quality from raw material that has deteriorated from the fresh condition, but canning is one process that permits some improvement to be made in some cases. Tuna, for example, which often arrives in a sorry state at the cannery, is drastically steamed before packed in the cans. This treatment drives off various volatiles of offensive odor and flavor, notably ammonia, amines, and lipid breakdown products, which accumulate in the flesh as a result of changes occurring during poor storage conditions.

Tanikawa et al. (158–64) investigated a number of questions arising in the manufacture of canned Japanese mackerel. Tanikawa and Yagi (164) concluded that to prepare a product of acceptable quality by the conventional methods, the material to be packed in the cans must contain no more than 20 mg/100 g volatile basic nitrogen. They measured the time required for this level to be reached in fish stored at various temperatures, and found that it could be computed (for temperatures below 25 C) from the equation:

$$\log(\text{time in hours}) = 2.14 - 0.048\,(\text{temperature of storage})$$

According to this, maximum storage time is 15 h at 20 C, and 46 h at 10 C; at 0 C the calculated time is about 140 h, but this was not experimentally confirmed. Tanikawa et al. (159) also reported that if the raw fish were stored too long, more than 12 h at 15 C for example, there was a tendency for the flesh to crumble after the canning.

Unfortunately, as the mackerel fishery is characterized by frequent gluts of fish to be processed, there may be times when it is impossible to avoid lengthy storage times. This is probably the reason that some of the canned product currently available is reported to be of poor quality. Mel'nikova and Khalina (101) reported that heat has very little effect on the extent of hydrolysis of glycerides during sterilization, but decomposes unstable peroxides to hydroxy acids and aldehydes. They pointed out that this would explain the increase in organoleptic defects during the canning of fat fish. Fish that have deteriorated beyond the desirable limit might perhaps be improved in quality before or after packing in the cans by steaming until the volatiles are driven off. There appears to be no report of this being done with mackerel, except for some work by Deschacht and Vansevenant (30) who found a weight loss of 11.2% during steaming of mackerel fillets. A much better approach is that of Hess (61) who provided detailed instructions for preparing canned mackerel from glut fish frozen round in brine and stored at –12 C or lower until they could be further processed. At that time they are thawed, dressed, and canned in the normal way, with the addition of a little dry salt yielding a product claimed to be of superior quality.

Tanikawa et al. (160) pointed out that packed and seamed cans should be sterilized without delay to reduce deterioration in subsequent storage at 15–25 C, and recommended that any delay should not exceed 40 min, or 60 at most. A curd of coagulated protein tends to form on the surface of the brine in canned mackerel. Tanikawa et al. (162) found this could be prevented by immersing the dressed fish for 30 min in 10–15% brine before canning. This procedure would, however, entail the loss of some of the protein from the flesh.

Fujita and Kishimoto (49) measured the heat conductivity of canned mackerel, and found there was a significant change in the range 50–60 C where the protein coagulates. Addition of oil to the fish in the can lowered the heat conductivity over the whole range of temperature. These properties govern the temperature attained in the can during sterilization and retorting.

The fate of the B-vitamins during canning of Japanese mackerel was investigated by Komata et al. (82). After processing, the mackerel retained 48, 93, 95, and 102%, respectively, of the original contents of thiamine, riboflavin, niacin, and vitamin B_{12}. During storage for 6 mo at 5–25 C there was a further considerable loss of thiamine, perhaps by oxidation, while the amount of the other three vitamins remained virtually unchanged.

Fujii et al. (48) proposed the ratio of inosinic acid to the sum of inosinic acid, inosine, and hypoxanthine as a quality index for canned mackerel, as they found it correlated well with quality judged by odor. One would like to know, however, whether there was also a good correlation with taste, as the development of persistent rancid flavors from deteriorating lipids is the usual complaint made against mackerel.

The occasional incidents of food poisoning by mackerel and tuna previously mentioned have usually been associated with canned products. The toxin involved is stable to heat and is not destroyed in the normal procedures used in canning and cooking (Kawababa et al. 75). It is therefore necessary to ensure that the fish to be canned has not been allowed to deteriorate until there is a risk toxin may be present.

SALTING AND SMOKING

The principles and practice of salting and drying fishery products, including mackerel, have been described in detail in a handbook by Jarvis (71), and instructions for packing pickled mackerel are to be found in Bulletin 19(1931) of the Fisheries Research Board of Canada (formerly the Biological Board of Canada). Consequently, only an outline will be given here. Although Indian Ocean mackerel (*Rastrelliger canagurta*) are dried in India (Sen and Lahiry 132; Rao and Khabade 126) fat fish do not usually dry successfully because the fats act as drying oils, and impart very strong flavors to the flesh. For this reason, Atlantic mackerel are not "dry-salted" and dried like cod, but are preserved in pickle. Normally, the fish are split and dressed as for canning, or are filleted. After rinsing in several changes of water, they are carefully packed in suitable containers, each layer being sprinkled with salt. To avoid putrefaction it is necessary to use at least sufficient salt to saturate the water contained in the fish, but skill is required to ensure thicker parts receive a proper share of salt and yet avoid wastage. On the other hand, it is essential that there are no thin spots, because this can lead to a red discoloration of bacterial origin (Beatty 16). Within a short time a pickle forms from the salt and the water is withdrawn from the fish, and the fish remain in this until "struck" (about 3 wk). They are then washed to remove any debris and repacked in saturated brine for marketing.

Murata and Oishi (104) investigated the spoilage at 37 C of salted and dried Japanese mackerel by measuring the production of ammonia at various levels of salt and moisture. For example, fish with 45% moisture and 10% salt had a shelf life of about 1 mo; this could be increased by increasing the salt concentration and/or reducing the moisture. The data presented refer presumably to the results of bacterial activity, and would not necessarily be related to loss of acceptability caused by degradation of the fat.

Chlortetracycline (CTC) has been tested as a preservative in preparation of lightly salted Japanese mackerel (Tomiyama and Sugitani 170). It was found that CTC added to a muscle homogenate containing 5% salt was gradually destroyed when stored at 4–12 C, and when the CTC fell below 2 ppm, putrefaction started.

There appears to be no other pertinent technical information concerning salt mackerel. It is conceivable that there might be a saving of labor cost and an improvement in quality if the fish could be salted by immersion in brine containing antioxidants, but some studies would be required to establish this.

Jarvis (71) also describes the smoking of mackerel, and should be consulted for details. Beatty (16) has emphasized that smoking is carried out mainly to impart a pleasant flavor, and cannot be regarded as a method of long preservation. This is confirmed by Houwing (67) who reported that smoked mackerel could be stored satisfactorily for 3 wk at 5 C, and less than 1 wk at 10 C.

COMMINUTED MACKEREL MUSCLE

There is considerable interest at present in the use of meat separating machines to recover edible muscle tissue from filleting waste presently consigned to fish meal and from fish now unutilized because of labor costs or market bias. Mackerel could conceivably be used in this way, provided the problem of rancidity can be controlled. Dol'bish and Noskova (36) removed part of the volatiles and other substances from minced muscle of Atlantic mackerel by washing with fresh water and then added stabilizers and antioxidants. The storage life at –20 C was 4.5 mo, but they found that the antioxidants did not extend this.

In Japan, minced fish is rinsed with water, mixed with preservatives such as certain sugars or amino acids, then frozen as a paste for eventual use in making fish sausage, and the cooked gel is called "kamaboko." Miyake and Tanaka (103) studied the effect of the pH of the fish paste on the kamaboko gel strength, and reported a product satisfactory in this respect could be made from Japanese mackerel. In commerce, however, the starting material appears so far to be limited to white-fleshed fish, mainly Alaska pollock and Atka mackerel (a misnomer, belonging to the greenling family that includes ling cod). Noguchi and Matsumoto (114–7) have extensively studied the role of amino acids, notably glutamic and aspartic, in controlling the denaturation of protein in minced flesh during frozen storage; this information may be applicable to mackerel should the need arise in the future.

BY-PRODUCTS

There exists very little literature dealing with by-products other than oil derived specifically from mackerel, and only two reports appear to be worth mentioning. Takenaka (157) published a review on insulin extracted from fish, notably mackerel and tuna. A West German patent (Dunn et al. 39) describes the preparation of an extract with beeflike flavor, for use in soups and sauces, from "boiling liquid" from tuna, mackerel, or herring. The preparation of some by-products, derivable from fish in general, might be applied to mackerel after suitable testing; for example, a British patent (Astra Nutrition AB, 14) mentions the recovery of nucleotides from the waste liquor obtained in the manufacture of a fish protein concentrate. A careful consideration of the economic factors involved frequently shows, however, that recovery of by-products is not feasible because of the small quantities available and the labor required; a notable instance of this would be the commercial preparation of insulin from fish.

CONCLUSION

There are many more references to Atlantic mackerel and its close relatives than have been cited in this review and bibliography, but they are either not pertinent, or appear to be of doubtful reliability. Some deal with standards in other countries, for example, and some with recipes and preparations that would not necessarily be acceptable to North American tastes. There are also a great many studies dealing with fish of other species, the results of which might be applied to mackerel. Any comments concerning such findings would be speculative until tests had actually been carried out on mackerel. It should be remembered, too, that some assessments of storage life cited were based on the judgments of taste panels in other countries and cultures, and may not be valid elsewhere.

Present technology, particularly that having to do with freezing, if properly applied, should be capable of reducing some of the problems encountered in the Atlantic mackerel fishery. Provided the catch is promptly frozen, the excess fish from inshore operations, as well as those from any offshore fishery, could be held long enough in good condition for subsequent processing without temporarily exceeding plant capacity. It is also conceivable that frozen fish could be successfully supplied to inland markets provided storage temperature and packaging were satisfactory. Nevertheless, available data and experience clearly indicate that development of rancidity is the problem that limits the storage life of Atlantic mackerel. For this reason, it appears unlikely the fish could be marketed in fresh (i.e. never frozen) condition except in areas close to where the inshore fish are caught. Even in frozen storage, present indications are that the maximum useful life is only about 6 mo at –20 C or lower. Although some investigations on this rancidity problem are now in progress in several laboratories, it seems clear that the studies so far reported in literature have not been either intensive or extensive enough as far as mackerel is concerned. The rise of the minced fish industry has increased the urgency of further work. The desirability of taking steps to suppress fat deterioration as soon as the fish are landed can scarcely be overemphasized. This would apply even to the production of canned mackerel, which, except for a possible prejudice against dark fish meat, ought to be an acceptable product if the successful canned tuna industry can serve as a guide. It should always be remembered, good food is not made from bad fish.

BIBLIOGRAPHY

This bibliography, while not professing to be complete, does contain many references not cited in the review. The references were obtained from Food Science Abstracts, Food Science and Technology Abstracts, Index to the Literature of Food Investigation, Commercial Fisheries Review, Biological Abstracts, Nutrition Abstracts, and Chemical Abstracts. They were selected to exclude items of only trivial or incidental interest with respect to mackerel, and those of mainly local concern, such as quality standards of specialized products. In most cases, the original abstracts are reproduced, but many have been edited to include only the material pertaining to mackerel. The abbreviations used for the journals cited were taken from the *Bibliographic Guide for Editors and Authors*, published in 1974 by the American Chemical Society.

Key to References by Topics

Additives: 44, 101, 106, 149, 171–2, 174, 176

By-products, sauces: 3, 39, 42, 64–6, 96

Canned: 22, 30–2, 48–9, 55, 61–2, 72, 74–6, 82, 94, 101–2, 107, 159–65, 180, 184

Comminuted (minced): 36, 77, 103, 181

Contaminants, trace elements: 3, 29, 38, 41, 47, 51, 53, 90–1, 123, 151–2, 170, 184

Economics, food habits: 9, 57–8, 68, 93

Extractives (TMAO, nucleotides, etc.): 12, 23, 40, 48, 70, 89, 98–9, 106, 127, 129–30, 137–44, 158, 165, 167–8

Filleted: 15, 62, 84, 125

Fish protein concentrate: 14, 24

Food poisoning: 54, 69, 102, 140–8

Frozen: 4, 6, 10, 15, 18, 28, 32–3, 44, 50, 59, 61, 84, 92, 101, 109–10, 119–20, 125, 154, 167, 179

Handling of fresh (unfrozen) fish: 6, 35, 46, 83, 112, 153, 166, 175

References

1 Ackman, R. G., and M. G. Cormier. 1967. α-Tocopherol in some Atlantic fish and shellfish with particular reference to live-holding without food. J. Fish. Res. Board Can. 24: 357–373.

Muscle tissue from four species of Atlantic fish (cod, dogfish, mackerel, and flounder) and one species of Pacific fish (sablefish) was examined for total lipid and α-tocopherol content. The values for α-tocopherol in both lean and fat major muscle tissues fell in the range 210–330 μg/g lipid. Lipids from cod and mackerel livers showed slightly higher values (430 μg/g lipid). These results are interpreted as a result of a lipid integration process in which the tocopherols produced by phytoplankton are redistributed with lipid through various lower life forms and small fish until similar levels are reached in the principal fats of larger fish.

2 ACKMAN, R. G., AND C. A. EATON. 1971. Mackerel lipids and fatty acids. Can. Inst. Food Technol. J. 4: 169–174.

The light and dark muscle of Atlantic spring mackerel differed sharply in lipid content, the dark muscle showing ~12% in spring males and 9% in females as against values of 2–3% for light flesh from both sexes. Fall mackerel had nearly twice as much fat in the dark muscle and 3 times as much in the light muscle. The fatty acid compositions of the total lipids of different muscle samples from three lots of fish and of triglycerides and phospholipids from muscles of another lot of fish are compared.

3 ADDISON, R. F., AND R. G. ACKMAN. 1974. Removal of organochlorine pesticides and polychlorinated biphenyls from marine oils during refining and hydrogenation for edible use. J. Am. Oil Chem. Soc. 51: 192–194.

Raw marine oils containing from 2 to 8 ppm DDT group pesticides, 0.00–0.03 ppm dieldrin, and 3–13 ppm polychlorinated biphenyls (as Aroclor 1254) were subjected to pilot plant refining, hydrogenation, and deodorization for margarine stock production. Residues of all three groups were reduced to below detectable limits (0.06, 0.01, and 0.5 ppm for Σ DDT, dieldrin, and polychlorinated biphenyls [determined as decachlorobiphenyl], respectively) as a result of processing.

4 AGZHITOVA, L. A. 1969. Quality assessment of frozen fish. Rybn. Khoz. 45: 53–55.

It was found that subcutaneous yellow coloring of the fat in some types of Atlantic fish (mackerel, sardine, sardinella) is caused partly by carotenoid pigments, and partly by oxidation products when the fats are turning rancid. The first stage of the process is the oxidation of carotene and decoloring of the subcutaneous layer; later stages comprise yellowing as a result of oxidation processes in the fat tissue. The origin of the yellow coloring was determined by spectrophotometric analysis in the UV and visible ranges.

5 AKIBA, M., T. MOTOHIRO, AND S. KUDO. 1967. Change in the amount of bound water in fish muscle during smoking. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 17: 234–241.

Changes in the amount of the bound water in Akta mackerel flesh during smoking were estimated. The absolute amount of bound water decreased during salting and also decreased with the reabsorbing of water during the desalting stage before smoking. Moreover, it decreased continuously during the smoking process.

6 ALMY, H. 1939. The composition and nutritive value of fish preserved by cold storage. Ph.D. Thesis, Columbia University, New York, N.Y. 25 p.

Investigations are reported on 1) the chemical composition of frozen fish after various periods of storage, 2) comparative rates of decomposition of fresh fish and frozen fish (after thawing), and 3) comparative organoleptic tests of fresh and stored fish. Mackerel were frozen and stored (1) uneviscerated and wrapped in semi-parchment paper, (2) gutted and not wrapped. Chemical analyses were made after 5, 8, and 9½ mo storage at a temperature of –21 to –15 C. Wrapping in paper retarded drying and oxidation processes and protected the exterior of the fish from mechanical damage. There was, however, no difference in keeping quality between wrapped uneviscerated mackerel and that of gutted unwrapped mackerel. From the chemical standpoint, fresh mackerel decomposed more rapidly than frozen mackerel after thawing. Bacteriological examination of fresh mackerel, butterfish, croaker, weakfish, sea bass, and flounder and of frozen mackerel showed that the bacteria in fresh and frozen fish increased about the same proportion during several days at icebox temperature. It was concluded that mackerel may be kept frozen satisfactorily for 10 mo.

7 AMANO, K., AND F. TOMIYA. 1950. Simplified test for the freshness of fish meat. V. Effect of freshness of fish meat on the stability of its aqueous extract against alcohol. Nippon Suisan Gakkaishi 15: 753.

Mackerel, tunny fish, and skipjack were used. To 10 g of flesh, 100 ml of distilled water were added, and to 1 ml of the extract, absolute alcohol was added from a burette at the rate of 2.0 ml per min. The quantities of alcohol required to produce 1) turbidity, and 2) precipitation, in the mixture were determined. The concentration of alcohol which caused coagulation of protein in the extracts was found to be 70–80% for fresh fish and 30–40% for decaying fish. In the presence of mercuric chloride, less alcohol was required to cause precipitation.

8 ANDERSON, M. L., AND M. A. STEINBERG. 1964. Effect of lipid content on protein–sodium linolenate interaction in fish muscle homogenates. J. Food Sci. 29: 327–330.

The effect of added fatty acid on protein solubility was studied in seven species of fish, including mackerel (*Scomber scombrus*). The proteins of muscles with higher lipid content showed greater stability. Linolenate uptake by natural lipids, resulting in competition between lipids and protein for added linolenate, is suggested. Some insight into the mechanism of the effect of lipids on protein–linolenate interaction was obtained from experiments on dogfish tissue extract. A low density, insoluble material was found in such extract which had a marked effect on dogfish protein stability. This material was largely lipid in character. A possible in situ relation of lipid hydrolysis to protein denaturation in frozen stored fish muscle is considered.

9 ANON. 1970. Fisheries under present and next five-year-plans. Pol. Marit. News 13: 18–19.

The capacity of the Polish fishing fleet increased from 163,700 tons gross in 1966 to 230,000 tons gross in 1969. This growth relates in the main to the large factory and freezer trawlers. Catches of fish increased from 280,100 tons in 1965 to 386,800 tons in 1969, the main species being 145,800 tons cod, 121,700 tons herring, and 271,000 tons mackerel. A similar growth of 30,000 tons/yr is foreseen for the 1971–75 period. To cope with the growing demand for salted herring, 50% of the new tonnage additions for 1971–75 will be designed for pelagic catches and salting at sea. Total catches should rise to 550–590,000 tons, and consumption should increase from 5 kg/head in 1968 to 7 kg/head in 1975. The decline of some traditional fishing areas and the growth of new ones is noted.

10 ANON. 1948. The use of ascorbic acid in frozen fish products. Quick-Frozen Foods 11: 66.

Preliminary work on the use of ascorbic acid as an antioxidant to retard rancidity in frozen fish is outlined briefly. In general, the effectiveness of ascorbic acid in this respect is related to the fat content of the fish; but it also appears to help to retain the natural color. Experiments have shown that the use of ascorbic acid can prevent a significant increase in the peroxide value of the fat of such fish as salmon, black cod (sable fish), mackerel, herring, and sole, and also has some retarding effect on the rise in peroxide value of the fat of cod, rosefish, and haddock. This effect is usually accompanied by a preservation of "fresh" taste and aroma. There is also some evidence that ascorbic acid may prevent the development of off-color in fish. The influence of sodium chloride in brining treatments is mentioned. Methods of commercial application are indicated.

11 ANON. 1972. Mackerel smoked by a new process. Food Eng. 44: 112.

A description is given of a new process for smoking mackerel. Cleaned, split mackerel are soaked in a brine solution, then hickory smoked at room temperature for 3–5 h. "Cold smoking" hardens the fish surface, sealing in the moisture. The fish are placed in cold storage for 24 h while the moisture diffuses through the meat. The next day they are "hot smoked" at (82 C) for 1 h, this cooks the meat, heightens the smokey taste, and colors the surface honey brown.

12 ARAI, K., AND T. SAITO. 1963. The organic phosphates in muscle of aquatic animals. XIII. Muscle levels of uric acid and nicotinamide adenine dinucleotide in fresh and frozen stored fish. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 13: 193–199.

Comparatively larger amounts of uric acid occur in the red lateral muscle than in the dorsal muscle for the mackerel, *Scomber japonicus*, and for the mackerel pike, *Cololabis saira*; but nicotinamide adenine dinucleotide (NAD) was more abundant in the fresh dorsal muscle. The uric acid concentration increased with the length of frozen storage, but there was no NAD in either muscle in frozen stored fish.

13 ARIMA, N., S. KATO, M. WATANABE, J. OSHIKA, G. KOIKE, AND A. KAGAWA. 1957. Loss of vitamin B_1 in raw fish and pork by cooking. Eiyo To Shokuryo 9: 310–312.

Salmon, mackerel, tuna, and pork were cooked by boiling, steaming, broiling, frizzling, or frying. Loss of vitamin B_1, about 20% in all cases, did not differ much by type of cooking.

14 ASTRA NUTRITION AB. 1969. Recovering nutritional elements from organic material. Brit. Pat. 1,140,005.

Organic material containing oil, proteins, nucleotides, and insoluble tissue in comminuted form is treated with an alkaline solution having a pH <12 and containing Ca at 3.5–17.5 g/kg organic material. The treatment is carried out at <40 for a time sufficient to liberate the oil and extract the protein. Three phases, an oil, sludge, and intermediate phase, are formed. The phases are separated and the protein is precipitated from the intermediate phase. Thus, a suspension of 2.0–3.5 kg. CaO in 750 liters H_2O is added to 250 kg fresh fish (tuna, cod, herring, or mackerel) and the mixture is homogenized for 2 min at 30–40 C with exclusion of air. The resulting mixture is opaque, free-flowing, and has a pH of 11.5–12.0; it is filtered through a metal sieve. The liquid passing through is centrifuged to produce the fat phase containing 93–97% of the total fat and 98–100% of the neutral fats, the sludge phase consisting of skeletal parts, collagens, cell membranes, and pigment tissue, and the intermediate phase containing 90–95% of the proteins and the greater part of the nucleotides. The proteins are precipitated by lowering the pH to 4–9, or by heating the solution. The precipitated proteins are filtered and dried to a powder. The nucleotides are separated from the supernate by filtration through charcoal and the remaining solution is vaporized.

15 BAUERNFEIND, J. C., E. G. SMITH, O. BATCHER, AND G. F. SIEMERS. 1948. Retardation of rancidity in frozen fish by ascorbic acid. Quick-Frozen Foods 10(8): 139; 10(9): 68.

Fresh fillets of mackerel (and other fish) were dipped in solutions of ascorbic acid at 1.5–4.5 C, wrapped in cellophane or Pliofilm, and quick-frozen. Tables show the evaluation of the frozen fillets treated in ascorbic acid solutions of varying strength, in water, and in brines for varying length of time, in the raw and cooked states, and after storage periods of several months at temperatures of −11 or −18 C. Retardation of enzymic oxidation and rancidity was most promising in the case of frozen fillets of mackerel and other fatty fish. The uptake of ascorbic acid by fresh fish fillets during dipping was also investigated. Fresh fillets were washed, drained, dipped, sprayed, or washed with solutions of the antioxidant, drained and immediately assayed for ascorbic acid content.

Most of the ascorbic acid was absorbed during the first 10–20 s of immersion and was roughly proportional to the concentration of the solution. Earlier work on retarding deterioration in frozen fish, and on other antioxidant materials, is reviewed briefly and suggestions are made for the commercial application of ascorbic acid to fish.

16 BEATTY, S. A. 1933. The reddening of salt mackerel. Fish. Res. Board Can. (Formerly Biol. Board Can.) Prog. Rep. Atl. Coast Stn. 6: 14–15.

17 BEATTY, S. A. 1947. Some principles of fish smoking. Fish. Res. Board Can. Prog. Rep. Atl. Coast Stn. 39: 9–11.

18 BOTALLA, G., O. BRUSS, A. DAGHETTA, AND A. MONZINI. 1956. Experiments on the preservation of fish fillets by freezing. Ann. Sper. Agrar. 10: 1651–1661.

Fillets of mackerel (*Scomber scombrus*), and other fish wrapped in Cryovac, Neothene (a polyethylene film), or cellophane film, were stored at −18 C for 6 mo. The changes which occurred in pH, contents of ammonia, trimethylamine, amino nitrogen, and tyrosine, peroxide value, and volatile acidity, were examined; results are tabulated. The chemical changes which appeared to be most injurious to the quality of the frozen fish are those concerned with the lipids, and especially those which lead to the oxidation of unsaturated fatty acids. The other changes did not seem to have any marked effect on the organoleptic quality of the product. The keeping quality of fillets depended mainly on the type of fish. The use of Cryovac resulted in greatly improved keeping quality and negligible loss of weight. Under the experimental conditions, the frozen fillets could be kept in good condition for 4 mo; by storage at a lower temperature (−25 C) in still air, they could probably be preserved for 6 mo or longer.

19 BOURY, M., AND J. SCHVINTE. 1932. Notes on studies of deterioration of fish. Rev. Trav. Inst. Peches Marit. 5: 311.

Note on studies of protein decomposition as measured by estimation of ammonia in the flesh of mackerel, and on observations of the fluorescence of fish flesh in Wood's light in relation to state of preservation.

20 BRAEKKAN, O. R. 1956. Function of the red muscle in fish. Nature (London) 178: 747–748.

During investigations of the vitamin contents of different organs from the tunny (*Thunnus thynnus*), samples from the deep-seated red muscle as well as from the neighboring ordinary muscle were analyzed for niacin, riboflavin, panthothenic acid, vitamin B_{12}, and thiamine. The results revealed an interesting relative distribution. With the exception of niacin, which showed a slightly higher value for ordinary muscle, the red muscle contained several times more of the other B vitamins than the ordinary muscle. Chemical analysis revealed that in most fishes the red muscle has a much higher fat content than the neighboring ordinary muscle; the values of the samples from mackerel, herring, and halibut were about 27–29%. If we further consider the relatively frequent high fat contents in the red muscle, and the fact that the white muscle contains no myoglobin and low contents of the B-vitamins except for niacin, it is likely that the main purpose of the red muscle is not muscular work, but that it functions as an organ. Finally, consider the presence of the red muscle in relation to the normal activities of the species. The anatomical situation of the red muscle prevents it taking part in the main muscular work. Further, of the species investigated, the tunny, as a very active and fast-swimming fish, has the highest proportion of red muscle. Next are mackerel and herring, which also move rapidly in shoals. On the other hand, halibut, as a flat fish, has less and a paler red muscle. Further considerations along these lines give the same general relation between activity and the extension and pigmentation of the red muscle in different species.

21 BRAEKKAN, O. R., AND G. BOGE. 1962. A comparative study of amino acids in the muscle of different species of fish. Fiskeridir. (Norw.) Skr. Ser. Teknol. Unders. 4: 1–19.

Amino acid percentages in protein were similar in the muscle of various fishes: cod (*Gadus morrhua*), coalfish (*Gadus virens*), haddock (*Gadus aeglefinus*), redfish (*Sebastus marinus*), catfish (*Anarrhichas lupus*), plaice (*Pleuronectes platessa*), halibut (*Hippoglossus hippoglossus*), ling (*Molva molva*), cusk (*Brosme brosme*), and mackerel (*Scomber scombrus*). Histidine was twice as high (4.5%) in mackerel as in flesh of other fishes. Cystine and possibly tryptophan were limiting among the essential amino acids.

22 BUFFA, A. 1955. Considerations of technical and economic aspects of the preparation of canned tunny and mackerel by improved processing procedures. Ind. Conserve 30: 3–6.

Improved procedures for the canning of tunny and mackerel fillets are described. Details are given of techniques used for heading and gutting, washing, autoclaving, centrifuging, sorting and packing, addition of oil, seaming of cans, and sterilization and cooking under pressure.

23 BULINSKI, R., AND K. KUTULAS. 1970. Choline content of freshwater and sea fish. Med. Weter. 26: 229–231.

Mean values with ranges in the muscle tissue are tabulated for 21 species of frozen fish from the Lublin market. The mean choline content in mackerel (*Scomber scombrus*) was 69 mg/100 g.

24 Continental Engineering, Ingenieursbureau voor de Proces Industrie N.Y. 1969. Evaporation of volatile organic compounds from foods. Neth. Pat. Appl. 68 00 702.

The removal of volatile organic compounds from foods is possible if the water content of the product is maintained between determined critical values (usually 7–15 wt% water) and if the process is carried out, after adjustment to the desired water content, by treatment with a gas (inert gas, steam, or a mixture of both). Thus, 10 kg deep-frozen mackerel is thawed quickly and ground (particle size $\leqq$2mm). By countercurrent extraction with *tert*-BuOH the particles are defatted and dehydrated. The mass is pressed to a residual water content of 70%. At 60 C, a mixture composed of 20 wt% water and 80 wt% N gas is run through the mass for 20 min, and the material is then dried with N gas at 70 C. The product has a water content of ~5 wt %, is nearly white, and, when suspended in boiling water, has only an extremely faint odor. No *tert*-BuOH was detected in the product (sensitivity of the gas chromatograph, 0.03 wt %).

25 Cutting, C. L., G. A. Reay, and J. M. Shewan. 1956. Dehydration of fish. Dep. Sci. Ind. Res. London Food Invest. Spec. Rep. 62: 159 p.

A description of four methods of dehydrating fish investigated during 1939–45. Fatty fish such as herring and mackerel yielded a dark-colored product of strong flavor; dehydrated kipper was generally preferred and had a somewhat longer storage life. Dehydrated fish was not a very attractive food, but could be convenient and acceptable in an emergency in the form of fish cakes, etc.

26 Darlan, L. A., C. B. Cabezali, P. J. Molinos, M. T. Pennimpede, and N. Ferrero. 1971. Bacterial flora of mackerel (*Scomber japonicus marplatensis*) during stages of industrial processing. Rev. Med. Vet. (Buenos Aires) 52: 311–312; 314–317.

Tests were made for eight classes of microorganisms at seven stages during the canning of mackerel and other fish. The freshly caught fish was almost free of microorganisms. The main increase in contamination occurred during evisceration and cutting, but this was reduced to almost nil during precooking. Some contamination occurred again during filling into cans which was almost entirely eliminated during the heat processing. Recommendations for improvements are made, e.g. to reduce delays by not overloading ports; to use small transport containers; to separate clean and dirty factory areas; and to use the Gram stain as a quick test.

27 Darlan, L. A., C. B. Cabezali, and M. T. Pennimpede. 1971. pH of fish muscle and its relation to freshness. Rev. Med. Vet. (Buenos Aires) 52: 473–474.

The pH of muscle tissue in eight species, including mackerel (*Scomber scombrus marplatensis*) was measured at daily intervals when stored at 6 C until spoilage occurred. It is concluded that pH cannot serve as an indicator of freshness.

28 DASSOW, J. A., S. R. POTTINGER, AND J. HOLSTON. 1956. Refrigeration of fish. IV. Preparation, freezing, and cold storage of fish, shellfish, and pre-cooked fishery products. U.S. Fish Wild. Serv. Fish. Leafl. 430: 124 p.

In this leaflet, fish, shellfish, and raw, breaded, or precooked seafoods are dealt with in three separate sections. Section I (p. 1–36) discusses the application to commercial fisheries of modern freezing methods. The first part is concerned with freezing of fish at plants on shore, and describes freezing of ground fishes (cod, flatfish, ocean perch and rockfish, halibut, sablefish), salmon, tunny and mackerel, herring, freshwater fish, and fish used as bait or animal feed. The second part is devoted to the freezing of fish (tunny, salmon, and trawl fish) at sea, including processing on board factory ships. Section II (p. 37–73) deals with oysters, prawns, lobsters, crabs, scallops, abalone, and clams, and includes descriptions of catching or harvesting, preparation for freezing (including correct packaging), and freezing and frozen storage. Section III (p. 75–124) presents a systematic treatment of the fish stick industry, its problems, techniques, and handling methods, with emphasis on the problems common to the production of all breaded foods. A short analysis of methods used in the preparation of frozen breaded shrimp, breaded fish squares, breaded abalone "steaks" (slices of a loaf prepared by molding minced fish under pressure), and fish pies, soups and chowders, and other products, is also included. Each section is fully illustrated.

29 DECOURCEY, M., AND E. D. GOLDBERG. 1962. Uptake and assimilation of radiostrontium by Pacific mackerel, p. lxxvi–lxxxi. *In* M. B. Schaefer [ed.] Oceanographic studies during operation "Wigwam." Limnol. Oceanogr. Suppl. 7.

Pacific mackerel were fed radiostrontium, which was measured in various organs over a period of 235 days. Ninety-five percent was excreted in 24 h. The remaining 5% remained fixed in the body throughout the duration of the experiment. Eighty percent of the fixed activity was in the calcereous portions of the fish. The gills showed the greatest activity per unit weight in 1–3 days after feeding, indicating that the radiostrontium was excreted by these organs during the period. After 2 days the flesh showed little activity.

30 DESCHACHT, W., AND A. VANSEVENANT. 1968. Changes in the water content during smoking and steaming of fish products. Landbouwwetenschappen te Gent 33: 1661–1673.

Investigation of the effect of (i) steaming at 82 C, (ii) cold smoking at 36 C, and (iii) cold smoking with 3 h preliminary drying, on the moisture content of herring fillets and whole herring and mackerel. Steamed mackerel lost 11.2% of the original weight. Initial and final moisture contents and product recoveries are tabulated and statistical analysis of results given.

31 DEWAR, A. B., AND K. B. SWANSBURG. 1972. The raw pack method of canning mackerel. MS Rep. Tech. Serv. Sect. (Unpublished data) Fish. Mar. Serv., Dep. Environ. Halifax, N.S. 22 p.

32 DIEUZEIDE, R., AND M. NOVELLA. 1950. The technique of the preservation of fish and other edible marine animals at low temperatures. Stn. Exp. Aquic. Peche, Castiglione, Algiers Bull. 151; Wildl. Fish. Abstr. 1(3): 37.

Thermodynamics, the properties of aqueous saline solutions at various temperatures, and the colloidal system of fish flesh and its saline and organic constituents are dealt with. The general principles of cold storage and freezing are discussed, as well as rates of freezing, and the specific heat and coefficient of heat conductivity of fish flesh. A series of tables gives information on the physical properties of various brines, freezing mixtures, and eutectic solutions. Effects of freezing on fish flesh are reviewed, including the formation of ice crystals and denaturation of proteins during slow and rapid freezing; changes in texture, color, flavor, odor, and general appearance; and loss of moisture. Practical aspects dealt with include the preliminary treatment of the fish, such as dressing and washing, and various methods of refrigeration, such as the use of ice (made from fresh or salt water) and solid carbon dioxide, freezing in brine and in air, and, especially, the various commercial methods of quick-freezing. Freezing installations on land and aboard fishing vessels, and cold storage plants, are described. Freezing of various species of fish and shellfish is explained individually, and also refrigeration of fish such as sardines, mackerel, and tuna before they are canned. Freezing of precooked fish dishes, defrosting of frozen fish, and packaging and transport of frozen fish are also considered.

33 DINGLE, J. R., AND J. A. HINES. 1975. Protein instability in minced flesh from fillets and frames of several Atlantic fishes during storage at −5 C. J. Fish. Res. Board Can. 32: 775–783.

Kidney tissue of cod and pollock, when mixed with the minced flesh of these fish, caused a rapid formation of dimethylamine and formaldehyde, and a concomitant loss of protein solubility, during frozen storage at −5 C. Kidney tissue of witch flounder, American plaice, and mackerel did not show this effect, and their minced flesh was relatively stable at −5 C. Minced flesh of witch flounder, when mixed with cod kidney tissue, deteriorated rapidly at −5 C.

34 DOESBURG, J. J., AND D. PAPENDORF. 1969. Determination of degree of heating of fish muscle. J. Food Technol. 4: 17–26.

Protein coagulation experiments using hake, mackerel, and pilchard after heating to known temperature in the range 60–100 C, are described. The effects of altering pH and of storage for several days at 2 C were also studied. Equations relating the maximum temperature of a heat treatment to the coagulation temperature of the extracted protein were derived for oily and lean fish.

35 DOHRENDORF, F. 1969. Process and device for filleting fish. West Ger. Pat. Appl. 1,579,433.

Process involves the mechanical removal of ribs from fillets cut from the back of fish. Fillets are taken by their inside flank across a base and are exposed to external pressure applied to the flanks, which straightens the ribs imbedded in them. Upon leaving the base, the ribs, which rebend, are loosened and lifted out of the fillet, starting from the bone furrow. Use relates to fish whose ribs are joined directly to the backbone, such as mackerel and perch, or those, such as cod, whose ribs are attached to processes of a vertebra.

36 DOL'BISH, G. A., AND V. I. NOSKOVA. 1971. Fish hash from Atlantic mackerels. Rybn. Khoz. 47: 66–68.

Hash from Atlantic mackerels was prepared. Part of the hash was washed with fresh water in the ratio 1:3. The washed samples contained $\sim \frac{1}{2}$ as many volatile compounds (16.4–22.0 mg/100 g as opposed to 28.8–33.6 mg/100 g). The values of the peroxide numbers were lower in the washed samples. When stabilizers (a mixture of salt, sugar, and sodium citrate) and antioxidants (0.01% butylhydroxytoluene, propyl gallate or butylhydroxyanisole) were added the acidities of the fats of the hash were lower. The largest water holding capacity was displayed by the unwashed hash with added stabilizer. The bacterial titer was higher in the washed samples. The storage time of the hash was 4.5 mo; the antioxidants did not extend the storage life.

37 DUBRAVCIC, M. F., AND W. W. NAWAR. 1969. Effects of high-energy radiation on the lipids of fish. J. Agric. Food Chem. 17: 639–644.

The volatile compounds formed in the lipid fraction of mackerel by γ irradiation under vacuum at 0.3, 2, and 6 mrad and at 0 and 25 were investigated. Using gas chromatography and mass spectrometry, 56 compounds, most not reported previously, were identified. Radiolytic products included the normal C_{1-17} alkanes, the C_{2-17} 1-alkenes, the C_{2-21} alkadienes, the internally unsaturated C_{14-21} alkenes, the C_{17} triene, the C_{11} alkyne, and the C_{16}, $C_{16:1}$, and $C_{18:1}$ normal aldehydes. Quantitative analysis demonstrated that the major products of irradiation were the longer-chain compounds, probably originating from radiolytic cleavage of the fatty acids near the carbonyl groups.

38 DUFFY, J. R., AND D. O'CONNELL. 1968. DDT residues and metabolites in Canadian Atlantic coast fish. J. Fish. Res. Board Can. 25: 189–195.

In mackerel, higher concentration of *p, p'*–DDT were found in the flesh and liver (<0.0.–2.75 ppm) than in the roe or brain (<0.01–1.98 ppm). Flesh was frequently found to contain *o, p'*–DDT at concentration of 0.03–0.69 ppm; it was occasionally found in roe, brain, and liver samples. The highest concentration of *o, p'*–DDT (1.65 ppm) was found in brain tissue. *p, p'*–DDD was found in 33% of the samples analyzed at concentration from 0.08 to 4.96 ppm. Higher concentration of p, p'-DDE, from <0.01 to 5.38 ppm., were found in the brain than in the liver, flesh, or roe.

39 DUNN, H. J., M. P. FARR, AND O. SCHLEUSNER. 1970. Meat extract substitute and process for its production. West Ger. Pat. Appl. 1,951,514.

Fish by-products or waste products, e.g. boiling liquid etc. from tuna, herring, mackerel, etc., are treated to extract fat and then condensed. The obtained soluble fish substance, containing 0.5% fat and 50% TS, is mixed with $\leqslant$10% of a reducing sugar, e.g. glucose. The mixture, at pH 6–9, is heated to 82–96 C for $\geqslant$4 h with constant agitation. A brown color forms, the fish flavor is replaced by a beeflike flavor, and the product contains 70–80% AS. Application is to sauces, soups, etc.

40 DYER, W. J. 1952. Amines in fish muscle. VI. Trimethylamine oxide content of fish and marine invertebrates. J. Fish. Res. Board Can. 8: 314–324.

Original determinations of the trimethylamine oxide content of 60 species of fish are recorded, and 21 additional species have been studied by others. Elasmobranchs have the highest content of oxide, 2–5% based on dry weight. Among teleost fishes, the amount increases from the lower to the higher orders, freshwater fish containing no oxide. Analyses of several species of marine invertebrates confirm earlier work showing that certain molluscs, echinoderms, and other organisms contain trimethylamine oxide, often in quantities similar to those in the higher teleosts.

41 ETCHEGARAY, M. L. 1969. Fluorine content of some Chilean seafoods. An. Fac. Quim. Farm. Univ. Chile 21: 41–44.

Mackerel contained 5.2 ppm fluorine. Benefits derived from ingesting F in this way are discussed.

42 EUROGA. 1964. Bifidus 2-containing products. Fr. Pat. 1,355,563.

Products rich in the factor bifidus 2 are prepared by the autolysis of the intestines of saltwater fishes, especially mackerel, whether the feces of the fish are present or not. The best conditions for the process, taking 2–10 h with agitation, are 50–55 C and pH 5.8–6.2 (regulated by an acid, such as HOAc, which has a taste unobjectionable to human beings). If the proportion of intestines in the starting material is <5%, a proteolytic enzyme, such as papain or ficin, is added in the amount of 0.05–0.2% by weight. The starting material is rapidly brought to its proteolytic temperature by the injection of steam of 105 C to destroy bacteria; the proteolysis is finished by the interaction of the enzymes by holding the mass at 70–80 C for at least 2 h. After the inactivation of the enzymes, the aqueous phase of the mass is separated and is heated at reduced pressure until a pasty residue is formed.

43 FEELEY, R M., P. E. GRINER, AND B. K. WATT. 1972. Cholesterol content of foods. J. Am. Diet. Assoc. 61: 134–149.

Cholesterol contents (per household measure, per 100 g edible portion and per 1 lb edible portion), arranged alphabetically according to the individual product, are given for many meats, poultry, fishes (including mackerel), shellfishes, and dairy products.

44 FIEDLER, R. H. 1940. Fishery industries in the United States, 1938. Preservation of fishery products for food. U.S. Dep. Commer. Boston Fish. Adm. Rep. 37: 201–203.

In studies of rancidity in fish, Boston mackerel treated with a water extract of the active principle of oat flour, and subsequently frozen, were found on examination over a period of 6 mo to be of superior quality to untreated fish and their appearance to be unaffected by the treatment. Further tests on the effect of water extract of oat flour on fresh, frozen, cured and kippered salmon and frozen halibut are in progress.

45 FIK, M. 1972. Activity of muscular cathepsins of some marine fish. Acta Ichthyol. Piscatoria 2: 105–111.

The cathepsin activity was determined in KCl extracts (1 M) of seven species of fish (including *Scomber japonicus colias*). The activity in pelagic fish was lower than that of fish residing in deeper waters when determined immediately after preparation. Results are discussed with reference to fish spoilage.

46 FRASER, D. I., D. P. PITTS, AND W. J. DYER. 1968. Nucleotide degradation and organoleptic quality in fresh and trawled mackerel held at and above ice temperatures. J. Fish. Res. Board Can. 25: 239–253.

In mackerel, by the time of initial sampling, adenine nucleotides had been deaminated to inosine monophosphate (IMP) in the ordinary muscle; in the red muscle the degradative sequence was even more advanced, as indicated by high initial levels of inosine. Postmortem rates of degradation of IMP to hypoxanthine through inosine were similar in both types of muscle; at ice temperature the rates were slower than in cod but faster than in swordfish. A delay in icing of 6–8 h after catching accelerated the gradual decline in eating quality with replacement of the characteristic fresh mackerel flavor by tastelessness. IMP dephosphorylation paralleled development of tastelessness, and spoilage (organoleptic) had developed prior to accumulation of appreciable amounts of hypoxanthine. At higher temperatures, 5–20 C, rates of IMP dephosphorylation, hypoxanthine accumulation, and quality loss were markedly increased. Thawing did not influence subsequent deterioration rates, but ascorbic acid dips delayed darkening of the flesh in the thawed samples. Excellent correlation of taste with both IMP and hypoxanthine content, and with various simple measures of IMP dephosphorylation, was obtained under the various handling conditions investigated, including delayed icing, holding at elevated temperatures, and after thawing. The simple tests—ultraviolet absorption at 248 mμ of a Dowex treated perchloric acid extract, and ratio of ultraviolet absorption of extracts at 251 mμ after Dowex treatment to that before treatment—proved as good indices of progressive quality loss to the unacceptability level as the more complex estimation of IMP or hypoxanthine.

47 Freeman, H. C., D. A. Horne, B. McTague, and M. McMenemy. 1974. Mercury in some Canadian Atlantic coast fish and shellfish. J. Fish. Res. Board Can. 31: 369–372.

All species of North Atlantic fishes studied, with the exception of two groups of offshore lobsters, had total mercury levels less than the 0.5 ppm limit allowed for fish of commerce in Canada and the United States. There appeared to be no relationship between mercury levels and the sex and/or weight of fish of any one species.

48 Fujii, Y., E. Noguchi, and Su Kuo-Hsiung. 1968. Relation between the quality of canned fish and its content of ATP decomposition products. I. ATP decomposition products in canned pink salmon and mackerel in relation to their inspection grades. Nippon Suisan Gakkaishi 34: 1031–1035.

With canned mackerel, the ratio of inosine monophosphate to the sum of hypoxanthine, inosine, and inosine monophosphate corresponded to the inspection grade; the larger the ratio, the less acceptable was the flavor. This is proposed as an index of quality.

49 Fujita, H., and A. Kishimoto. 1956. Studies on physico–chemical properties of marine products and related substances. V. Heat conductivity of fresh fish meats. Nippon Suisan Gakkaishi 22: 306–310.

A method is described for determining the effect of heating fish muscle on its heat conductivity. The curves obtained with mackerel packed in a flat can were sigmoidal, with an inflexion point in the range 50–60 C, corresponding to the coagulation temperature of the muscle proteins; addition of oil lowered the heat conductivity over the whole range of temperature investigated. Heat conductivity depends relatively little on temperature, but enough to have a marked influence on the rate of temperature at the center of a can.

50 Gheorghe, V., M. Manea, D. Bad-Oprisescu, and F. Jantea. 1970. Preservability and sanitary control of frozen ocean mackerel (*Scomber scombrus*). Igiena 19: 601–609.

Samples of mackerel from a batch caught in the Canary Islands region, frozen at −40 C and stored on the trawler for 2 mo at −20 C, were stored experimentally at −18 C and at from −8 to −10 C and were examined at monthly intervals for $\leqslant 8$ mo. Further samples of frozen mackerel were placed in refrigerated storage at 6 or 8 C and were examined 4, 7, and 11 days later. Values for contents of i) ammonia N, ii) trimethylamine, and iii) histamine as well as for counts of, iv) total, v) psychrophilic, vi) proteolytic, vii) coliform, and viii) *Proteus* spp. bacteria are tabulated. (i) Is considered a more sensitive indicator than (ii) of initiation of spoilage; (iii) was not found suitable for freshness assessment though useful as a measure of toxicity. No (vii) or (viii) were detected in frozen samples and (iii) contents were always below the toxic limit even after storage at 6 or 8 C. Numbers of (iv) and (v) did not change in frozen storage for 7 mo but increased rapidly, and those of (vi) slowly in storage at 6 or 8 C.

51 Goeij, J. J. M. de, and C. Zegers. 1971. Mercury in fish. III. Mercury contents of some imported canned fish. TNO Nieuws 26: 400–401.

Neutron activation was used to determine Hg contents of canned fish from 18 countries. Mean concentration (ppm) in seven samples of mackerel was 0.067 (0.053–0.082).

52 Grangaud, R. 1950. Vitamins of fish. Cong. Int. d'Étude sur le Rôle du Poisson dans l'Alimentation, Paris, 1950. p. 83.

A comprehensive review of work on the subject. Fish provide particularly rich sources of vitamins A and D (fish liver oils and flesh of fatty fish), and vitamin E (cod roe, flesh of mackerel and sardine). Vitamins B_1 and B_2, nicotinic acid, pyridoxine, and panthothenic acid, are present in fish muscle to about the same extent as in meat, and in higher concentrations in fish livers and roes. Low values have been found for folic acid in fish, but the method may have been unsatisfactory. The animal protein factor is present in fish. The concentration of vitamin C in fish muscle is about the same as in meat; salmon has a particularly high content (richer than orange juice) and fish livers and roes are also good sources. Reference is made to the effects of cooking, canning, and preservation by smoking and salting, on the vitamin content of fish.

53 Greve, P. A., and S. L. Wit. 1971. Mercury in fish. II. Total Hg content in fresh- and sea-water fish. TNO Nieuws 26: 395–399.

Neutron activation was used to determine Hg contents of five samples of mackerel (among other species); the mean value (ppm) was 0.34 (0.22–0.59).

54 Halstead, B. W., and D. A. Courville. 1967. Poisonous and venemous marine animals of the world. 2: 639–668. U.S. Gov. Print. Off. Washington, D.C.

55 HARDY, E. 1969. Notes on fish and shellfish. Can. Pack. 39: 6.

The method of packing mackerel in Denmark, USA, Australia, and South Africa is briefly outlined. Cutting and cleaning of the mackerel and occasional brining before canning is also discussed.

56 HARDY, R., AND J. N. KEAY. 1972. Seasonal variations in the chemical composition of Cornish mackerel, *Scomber scombrus* (L), with detailed reference to the lipids. J. Food Technol. 7: 125–137.

Proximate analyses and determinations of mean lipid unsaturation have been performed on monthly samples of *Scomber scombrus* (L) caught off the Cornish coast throughout a period of 1 yr (December 1968–November 1969). Maximum and minimum total-lipid levels were recorded in December and June respectively. The highest mean lipid unsaturation levels were recorded in November and the lowest in May. An inverse linear relationship between lipid and water content with protein level remaining substantially constant was observed. Biometric data were collected on samples of June and December fish and detailed lipid analyses performed on the flesh, liver, and gonad. Prominent features of the data are discussed and some comment made on the nature and functions of lipids in fish.

57 HATANAKA, M., K. SEKINO, M. TAKAHASHI, AND T. ICHIMURA. 1957. Growth and food consumption in young mackerel, *Pneumatophorus japonicus* (Houttuyn). Tohoku J. Agric. Res. 7: 351–368.

Young mackerel, caught at sea, ate mainly pelagic crustaceans, especially Euphausia, from April to mid-July, and from then until October they ate fish, mainly anchovy. Relation of growth to food intake is plotted, and shown in tables. Efficiency of conversion was much less with Euphausia than with amounts of anchovy of similar energy value. Growth rates were higher in tank experiments than in fish caught in the sea.

58 HATANAKA, M. A., AND M. TAKAHASHI. 1960. Studies on the amounts of anchovy consumed by the mackerel. Tohoku J. Agric. Res. 11: 83–100.

It was confirmed that mackerel eat mainly anchovy and other small fishes from July to October and large pelagic crustaceans, especially euphausiids during the rest of the year. Daily weight gains during these feeding periods were 0.30–0.50 and 0.10–0.16%, respectively. The average weight of mackerel caught was 300–400 g. It was calculated that, although catches of anchovy had been rising between 1953 and 1958 and those of sardines had been falling, more than twice as many anchovy were eaten by mackerel as were caught. There is considerable overlap of season of predation and of fishing and of size of anchovy taken by both means.

59 HELGERUD, O. 1954. The Protan process for the freezing of fish. Kältetech. 6: 190–193.

Alginates made by the Norwegian firm Protan were used experimentally in block-freezing herring. To lower the freezing point of the alginate gel, salts were added; dilute lactic acid was also added to indicate the time of gel formation. A long-term freezing experiment showed that herring frozen by this procedure were of good quality and compared favorably with fresh fish. The alginate gel exerted a protective action and the separation of the fish was facilitated and the tendency to stick on thawing was eliminated. Even after storage for a year, the herring were quite suitable for curing. The technique is said to be particularly useful with fish fillets.

60 HERZBERG, A., AND R. PASTEUR. 1969. Proximate composition of commercial fishes from the Mediterranean Sea and Red Sea. Fish. Ind. Res. 5: 39–65.

Ten species were examined on a year-round basis. Mackerel (*Scomber japonicus*) contained: protein, 22.2% (20.8–23.2); oil, 3.3% (1.4–7.6); ash, 1.8% (1.5–2.4); solids, 26.7% (24.7–30.5).

61 HESS, E. 1931. The canning of brine-frozen mackerel. Bull. Fish. Res. Board Can. (formerly Biol. Board Can.) 24: 13 p.

Gives details of processes used for brine-freezing fresh mackerel, and cold storage and canning of the brine-frozen fish.

62 HESS, E. 1935. Canning mackerel fillets. Fish. Res. Board Can. (formerly Biol. Board Can.) Prog. Rep. Atl. Coast Stn., 14: 8 p.

Gives details of cannery equipment and materials required and instructions for canning mackerel fillets.

63 HIGASHI, H., S. MURAYAMA, AND K. TABEI. 1954. Studies on the variation of lipid in discoloration of salted and dried fish. Nippon Suisan Gakkaishi 20: 741–749.

Discoloration of fillets of salted mackerel is associated with the formation of conjugated double bonds in the fatty acids of the surface lipids. These lipids tend to increase in concentration in the inner surface layer, and to cause discoloration there, whereas the remaining lipids in the skin and interior layers undergo less change.

64 HOSHINO, N. 1962a. Change of amino acid contents during fermentation of mackerel muscle. I. Assay method for free amino acids in fresh and fermented muscle. Food Res. Inst. (Tokyo) Res. Rep. 16: 39–42.

Methods of deproteinization to prepare a solution for microbiological assay were studied. Tungstic acid was satisfactory. With

samples containing high amounts of basic amino acids the concentration of the test solution should be controlled because basic amino acids may precipitate with the protein. The muscle was especially rich in histidine.

65 HOSHINO, N. 1962b. Change of amino acid contents during fermentation of mackerel muscle. II. Amino acid contents of autolyzed and fermented muscle of mackerel. Food Res. Inst. (Tokyo) Res. Rep. 16: 43–46.

Total amino acids were determined after acid hydrolysis. In autolysis of ordinary mackerel muscle, liberation of each amino acid proceeded in proportion to incubation time but at different rates. Leucine, histidine, lysine, threonine, and serine were liberated rapidly. In the fermentation with *B. mesentericus* and *B. subtilis* arginine, histidine, tyrosine, serine, and threonine decreased during incubation, while leucine, lysine, methionine, and valine did not change.

66 HOSHINO, N. 1963. Changes of amino acids during the putrefaction of muscle of mackerel. Nippon Shokuhin Kogyo Gakkaishi 10: 5–8.

Ordinary muscle of mackerel was mashed and stored at 23–30 C. Changes of arginine, histidine, lysine, tyrosine, cystine, methionine, serine, threonine, leucine, valine, and aspartic acid were analyzed by bioassay for 188 h. Only alanine increased to 120% but all the other amino acids decreased to 52–76%. N soluble in hot H_2O and α-amino N increased during putrefaction while the total N decreased.

67 HOUWING, H. 1971. Preliminary tests on the prepackaging of fish and fish products. Voedingsmiddelen Technol. 2: 3–9.

Smoked mackerel were packaged in gas-permeable MSAT cellophane or polyethylene (PE) or one of two grades of impermeable Heliotheen, a polyester/polyvinylidene chloride/PE laminate, the latter with or without vacuum, or under CO_2 or N_2. The samples were stored at 1–10 C, and examined at various intervals organoleptically, for aerobic count and contents of total volatile basic N. On the basis of the results, given in a series of tables, it is concluded that smoked mackerel can be stored satisfactorily in Heliotheen for 3 wk at 5 C, but less than 1 wk at 10 C.

68 HOY, D. L., AND G. M. CLARK. 1967. Atlantic mackerel fishery 1804–1965. U.S. Fish Wildl. Serv. Fish. Leafl. 603: 9 p.

69 IGARASI, H. 1938. Pungent principle of spoiled fish J. Chem. Soc. Jpn. 59: 1258.

The pungent principle isolated from partly spoiled fish such as sardine, mackerel, skipjack, and bluefin tuna was found to be histamine. Food poisoning from eating partly spoiled fish, therefore, may be attributed principally to histamine.

70 INAGAKI, C., H. FUKUBA, AND A. KANO. 1959. Ascorbic acid content of fish. Bitamin 16: 234–236.

Fifteen species of fresh fish were studied for their ascorbic acid (I) content (indophenol method, 2, 4- dinitrophenylhydrazine method, paper chromatography). The highest content of I was found in horse mackerel (*Trachurus trachurus*) (2.10 mg/100 g), and the lowest in mackerel (*Scomber japonicus*) (0.33 mg/100 g). The internal organs contained I in the order liver > kidneys > heart.

71 JARVIS, N. D. 1950. Curing of fishery products. U.S. Fish Wildl. Serv Res. Rep. 18: 271 p.

A reference handbook, dealing with the principles and the standard and improved methods for drying, salting, curing, and smoking fish. A comprehensive bibliography is included.

72 JARVIS, N. D., AND J. F. PUNCOCHAR. 1939. The home canning of fishery products. U.S. Bur. Fish. Invest. Rep. 34 (revised).

After a brief discussion of principles involved in home canning of sea foods, with special reference to 1) the relation of microorganisms to canning and 2) sterilization, equipment required, and canning procedure are described in detail (including transport, handling, grading and preparation of raw material, processing, and storage). Recommended canning procedures are given for herring, roe, carp, suckers, mackerel, lake trout, whitefish, mullet, salmon, shad, spiced fish, tuna, whiting, clams, oysters, crab, shrimp, fish chowder, etc. Examination of the canned product, and the unsuitability of certain fishery products for canning, are also discussed.

73 KARRICK, N. L., W. CLEGG, AND M. E. STANSBY. 1957. Vitamin content of fishery by-products. III. Riboflavine, nicotinic acid, vitamin B_{12}, moisture, oil, ash, and protein content of commercial fish meals. Commer. Fish. Rev. 19: 14–23.

Commercial herring, mackerel, menhaden, sardine, and tuna meals of known history were assayed in duplicate at four concentrations. Mackerel meal averaged 5.6% moisture, 10.7% oil, 60% protein. Vitamin contents (for all meals, oil and moisture-free) were riboflavine, 2.6–8.9; nicotinic acid, 42–178; and B_{12}, 0.20–0.52 γ/g.

74 KAWABATA, T., K. ISHIZAKA, AND T. MIURA. 1955a. Studies on the food poisoning associated with putrefaction of marine products. I. Outbreaks of allergylike food poisoning caused by samma sakuraboshi (dried seasoned sauri) and canned seasoned mackerel. Nippon Suisan Gakkaishi 21: 335–340.

Food poisoning caused by consumption of dried saury and of canned mackerel took the form of flushes, dizziness, and headache, with no abdominal symptoms. The fish products had normal pH values and contents of volatile base nitrogen and trimethylamine, but abnormally high contents of histamine; extracts had more marked vagus-stimulating properties than could be accounted for by the amount of histamine present.

75 Kawabata, T., K. Ishizaka, and T. Miura. 1955b. Studies on the food poisoning associated with putrefaction of marine products. II. Causative toxic substance and some of its chemical properties. Nippon Suisan Gakkaishi 21: 341–346.

The unknown vagus-stimulant present in toxic samples of dried saury and canned mackerel was isolated from a methanolic extract by chromatography on paper; it gave a brownish-purple spot with ninhydrin, and had a different R_F from histamine; it was about 9 times as active as histamine physiologically. It was insoluble in ether, benzene, chloroform, and absolute ethanol, fairly stable to heat, and dialysable.

76 Kawabata, T., K. Ishizaka, and T. Miura. 1955c. Studies on the food poisoning associated with putrefaction of marine products. III. Physiological and pharmacological properties of newly isolated vagus-stimulant, named saurine. Nippon Suisan Gakkaishi 21: 347–351.

The vagus-stimulant isolated from toxic samples of dried saury and canned mackerel differs from acetylcholine; its physiological effect appears to be additive with that of histamine. It was more markedly antagonized by antihistamine drugs than by antiacetylcholine drugs. The name saurine is suggested for this histaminelike substance.

77 Kawashima, T., H. Oshima, and K. Hashimoto. 1967. Water-bleaching of marine products. I. The quantity of protein washed out in the bleaching of fish meat. Hokusuishi Geppo 24: 502–510.

Large amounts of Alaska pollack and Atka mackerel are caught in the waters adjacent to Hokkaido. After removing the water-soluble proteins by bleaching, their meats are processed in frozen fish paste surimi which is one of the most important fish products on Hokkaido. In one processing plant, 53–77% of water-soluble N was washed out by three washings; 56–86% by five washings. The concentration of water-soluble N in the first drainage was 0.036–0.056%, while 0.022–0.066% N was determined in the drainage by a centrifugal drier.

78 Ke, P. J. 1975. The proposed rancidity indexes for mackerel and its application to compare the storage life of various frozen mackerel. Fish. Res. Board Can. Halifax Lab. New Ser. Circ. 52: 8 p.

79 Ke, P. J., R. G. Ackman, B. A. Linke, and D. M. Nash. 1975. The rapid development of rancidity in the skin of frozen mackerel. Fish. Res. Board Can. Halifax Lab. New Ser. Circ. 53: 8 p.

80 KITAMIKADO, M., AND H. YAMAMOTO. 1969. Distribution of hyaluronidase in fish tissues. Nippon Suisan Gakkaishi 35: 466–470.

Hyaluronidase was demonstrated in extracts from the liver, heart, kidney, and digestive tract of *Scomber japonicus*, as well as other marine animals. The enzyme was not demonstrable in testes of most fish. There is a large amount of hyaluronidase in the extracts from stomachs of certain carnivorous fish. The properties of bacterial hyaluronidase were different from those of fish stomach enzyme; the bacterial enzyme was not responsible for the enzyme action in the stomach extracts.

81 KLAWE, W. K., I. BARRETT, AND B. M. KLAWE. 1963. Hemoglobin content of the blood of 6 species of scombroid fish. Nature (London) 198: 96.

According to comparisons of several methods, hemoglobin (I) determinations made by the pyridine hemochromogen method, demonstrated that the concentration of I was higher for the six scombroids (*Scomber japonicus*, *Sarda chiliensis*, *Thunnus albacores*, *Katsuwonus pelamis*, *Euthynnus lineatus*, and *Auxis rochei*) than for other groups as reported in the literature.

82 KOMATA, Y., Y. HASHIMOTO, AND T. MORI. 1956. B-Vitamins in marine products and their changes in the processing and storage. I. Canned mackerel and tuna in brine. Nippon Suisan Gakkaishi 21: 1236–1240.

After processing in ½-lb cans, mackerel retained 48, 93, 95, and 102%, respectively, of the original contents of thiamine, riboflavin, niacin, and vitamin B_{12}; corresponding figures for tuna were 30, 84, 87, and 96%. During storage for 6 mo at room temperature (5–25 C), canned mackerel and tuna retained almost unchanged the amounts of riboflavin, niacin, and vitamin B_{12} present after canning; a considerable amount of thiamine was lost, perhaps by oxidation. The liquid portion of the canned fish contained 10–20% of the total amount of vitamins.

83 LEMON, D. W., AND L. W. REGIER. 1976. Refrigerated seawater holding of mackerel. J. Fish. Res. Board Can. (In preparation)

Refrigerated sea water proved to be a superior method of holding mackerel. The uniform, lower temperature and reduction in available oxygen retarded the development of oxidative rancidity. Textural deterioration was also retarded. The sodium uptake from and the potassium loss to the sea water by the mackerel was not excessive, and taste panelists could not consistently identify samples with elevated salt contents. The addition of carbon dioxide to the RSW did not regularly affect the level of spoilage as monitored by the measurement of trimethylamine. The values, however, were low for all holding systems, even after 9 days. The presence of dissolved carbon dioxide in the fish muscle made the fish unacceptable for canning.

84 LILJEMARK, A. 1964. Cold storage of retail-packed fillets of mackerel and herring. Food Technol. 18: 122–124.

Storage tests with fish fillets in heat-sealed film bags were made to compare the effects of various treatments against oxidative rancidity with that of a temperature reduction from −20 to −30 C. Dipping the fillets in 2% ascorbic acid or evacuating the bags improved the quality retention about as much as the temperature reduction, and vacuum-packing combined with enzymic O uptake (addition of a glucose oxidase–catalase–glucose mixture) was as effective at −20 as vacuum-packing alone at −30 C.

85 LOHNE, P., AND A. O. UTVIK. 1971a. Production of meal and oil from fish material. Norw. Pat. Appl. 122,626.

Meal and fat or oil are produced from fish material by preparing an aqueous suspension of comminuted fish material; separating the aqueous suspension into a DM phase and a fat-containing aqueous phase by centrifugation, preferably in two or more centrifuges connected in series; and recovering the fat or oil from the aqueous phase. The first two stages are carried out without application of heat. The process gives a fish meal which has a low fat content, good storage properties, and is suitable for use as a food. Preferred fish are herring, mackerel, and other high-fat fish.

86 LOHNE, P., AND A. O. UTVIK. 1971b. Production of meal and oil from fish materials. Nor. Pat. Appl. 122,627.

Meal and oil are produced from suitable fish material, e.g. herring and mackerel, by heating the fish material, optionally together with water, to 50 ± 5 C, separating the oil from the heated mass by a known method, e.g. screw press, and drying the meal. The first stage is carried out without previous comminution of the fish material. The meal obtained has a low fat content, good storage properties and is suitable for use as a food.

87 LOPEZ-BENITO, M. 1971. Use of caustic soda to treat mackerel, horse mackerel and sardine before canning. Invest. Pesq. 35: 531–547.

NaOH was used to skin both whole and cleaned fish to save work in canning factories. In general, a 2% NaOH bath at 60–80 C for 2 min gives fair results. A detailed description of experiments is presented. After treatment with NaOH, fish are washed in water and neutralized with citric acid. A testing panel found practically no difference between hand-skinned canned fish and fish canned after being skinned with NaOH.

88 LUHMANN, M. 1956. Fat storage in the mackerel (*Scomber scombrus* L.). Arch. Fischereiwiss. 7: 61–74.

The fat content of mackerel caught in 1954–55 was studied in relation to growth and the sexual cycle. In general, it fluctuated (from 0.5 to 18.3%), average values being 7–14%; the lowest value was found during

the spawning season (May–July). The relationships between fat content and dry matter content and the length–weight coefficient were calculated. The proportion of fat-free matter was found to be 21.5% in adult, and 19.7% in immature fish. The weight of mackerel increased with increasing fat content; in contrast to the herring, the computed weight of the fish in which there is no increase in fat content rose continuously.

89 LUKTON, A., AND H. S. OLCOTT. 1958. Content of free imidazole compounds in the muscle tissue of aquatic animals. Food Res. 23: 611–618.

An ion-exchange column was used to survey the amounts of anserine, carnosine, histidine, and L-methylhistidine in the muscle fibers of 23 species of marine fishes, 2 freshwater fishes, 2 elasmobranchii, and 6 molluscs and crustacea. Ten to 50 μmoles/g each of anserine and histidine were found in the four tuna species. Sablefish and salmon had large amounts of anserine only, 11–25 μmoles/g. Mackerel, sardines, and menhaden had large amounts of histidine only, 15–49 μmol/g. Light meat of these fish contained more imidazole compounds than did the dark meat. Large variations in imidazole content were found with different individuals of the same species.

90 LUNDE, G. 1972. Analysis of arsenic and bromine in marine and terrestrial oils. J. Am. Oil Chem. Soc. 49: 44–47.

Two oil samples (cod liver oil and oil extracted from mackerel fillets) were fractionated on silica gel columns and Br was determined in the different fractions. The results obtained indicate that lipid-soluble Br and As organic compounds are characteristic components of marine animal and marine plant oils (seaweed). The results also show that the Br is not localized in any pacticular compound or type of compound. The Br-containing compounds seem to be relatively stable, but the As-containing compounds are not. When oils containing As and Br were saponified, some of the As and Br compounds were found in the fatty acid fraction while others appeared in the water soluble fraction.

91 LUNDE, G. 1973. The analysis of organically bound elements (As, Se, Br) and phosphorus in raw, refined, bleached and hydrogenated marine oils produced from fish of different quality. J. Am. Oil Chem. Soc. 50: 26–28.

Marine oils have been produced in pilot plant by boiling, pressing, and separation of the press liquor from raw material (mackerel and herring) of different levels of spoilage. The difference in quality is obtained by varying the period of storage. Some oil samples have been refined and hydrogenated. In samples taken both from the raw oils and from oils at the different steps in the processing, organic bound As, Se, Br, and P are analyzed. When the raw material deteriorates during storage, an increase in the Se and P content in the oils produced from these materials is observed, whereas the Br and the As content is nearly constant. During the refining the As and P disappear almost completely from the oils, whereas the Se content is reduced to about two-thirds and the Br content is nearly unaffected. In the hydrogenation step the Se disappears relatively fast and the Br more slowly.

92 LYUBAVINA, L. A., K. I. PAKHOMOVA, L. D. KHOBOTILOVA, AND G. M. DUBNITSKAYA. 1972. Determination of quality of frozen herring. *Polomobus aestivalis*, and mackerel. Rybn. Khoz. 4: 67–69.

The causes of fat spoilage and oxidation processes were investigated. Peroxide number, thiobarbituric acid test, and carbonyl compound content were determined. The fat was centrifuged from the tissue following brining. Taraxantine carotenoids penetrate quickly into the subcutaneous layers, causing yellow-orange pigmentation within 1–2 h prior to freezing of mackerel and within 3–4 h in herring. Pigmentation of the frozen tissues depends on storage conditions. Carotenoid content increases initially, and falls later. Complete decomposition of carotenoids takes place only when considerable oxidation takes place, the peroxide content reaching 1.5–2.5% of iodine. Yellow pigmentation of the fat is, therefore, due to accumulation of oxidation products.

93 MACKAY, K. T. 1967. An ecological study of mackerel *Scomber scombrus* in the coastal waters of Canada. Fish. Res. Board Can. Tech. Rep. 31: 127 p.

94 MACKIE, I. M., AND T. TAYLOR. 1972. Identification of species of heat-sterilized canned fish by polyacrylamide-disc electrophoresis. Analyst (London) 97: 609–611.

The heat-denatured proteins of canned fish obtained by treating the fish with cyanogen bromide yield polypeptides that are soluble in 6 M urea solution. These fragments of proteins, which have been cleaved selectively at the methionyl peptide bond, can be separated by electrophoresis in 6 M urea solution. The separation patterns for canned herring, tuna, plaice, salmon, lemon sole, sprat, haddock, and mackerel are presented. The method extends the electrophoretic method of species identification to include canned fish.

95 MAKINODAN, Y., AND S. IKEDA. 1969. Studies on fish muscle protease. I. On the existence of two kinds of proteases active in acid and in slightly alkaline pH range. Nippon Suisan Gakkaishi 35: 672–676.

All species produced active acid proteinases with optimal activity around pH 3.0–3.5. The alkaline enzymes were not found in common mackerel, sardine, yellowtail, and cod, but were present in carp and red sea bream with optimum pH at 8.0, and present but only weakly active in albacore, frigate mackerel and horse mackerel. The two types had widely different temperature-activity curves, with optimum temperature (4 h reaction) of 60–65 C for alkaline proteinase and 45–50 C for acid proteinase.

96 MANITA, H., C. KOIZUMI, AND J. NONAKA. 1969. Aseptic autolysis of mackerel muscle. Nippon Suisan Gakkaishi 35: 1027–1033.

The autolysis of mackerel muscle was investigated under strictly aseptic conditions without the addition of any antiseptics. The autolysis of the mackerel muscle homogenate proceeded readily at 45 C at pH 3.5 and at 60–65 C in a slightly alkaline pH range. Antiseptics such as toluene, $CHCl_3$, and thymol did not affect the optimum pH (3.5) of autolysis at 45 C but considerably lowered the rate of autolysis. These antiseptics inhibited the brown discoloration and fat oxidation of the mackerel muscle homogenate during the autolysis.

97 MANNAN, A., D. I. FRASER, AND W. J. DYER. 1961. Proximate composition of Canadian Atlantic fish. II. Mackerel, tuna and swordfish. J. Fish. Res. Board Can. 18: 495–499.

Mackerel, tuna, and swordfish (order Acanthopteri) have a prominent red or dark brown fatty lateral-line tissue, which in the samples analyzed, had a lipid content varying from 6% in swordfish to 22% in mackerel. A white blubber or layer of fat tissue, almost two-thirds lipid, may also be present beneath the skin. The white meat was also fatty, from 2% in swordfish to 8% in tuna. The belly-flap muscle of mackerel contained from about 20 to 40% fat. Protein, ash, and moisture percentages were lower in the fatty tissue, showing that fat replaces some protein as well as water. Nonprotein nitrogen average 20% of the total nitrogen, higher than in halibut and the cod family. In tuna and mackerel the protein content was 19% in the white meat, and 14% in the brown lateral-line tissue, similar to halibut but higher than in the cod family.

98 MANO, T., AND T. SENJU. 1969. Distribution of carnosine in several species of fish and shellfish. Eiyo To Shokuyro 22: 164–167.

Negligible amounts of carnosine were found in skeletal muscles of mackerel.

99 MATSUURA, F., AND K. HASHIMOTO. 1954. Chemical studies on the red muscle ("Chiai") of fishes. II. Determination of the content of haemoglobin, myoglobin, and cytochrome C in the muscles of fishes. Nippon Suisan Gakkaishi 20: 308–312.

Data are given for amounts of the three proteins in the red and ordinary muscles of nine species of fish, including *Scomber japonicus*. In general, red muscle was considerably richer in these pigments than the ordinary muscle.

100 Matsuura, F., S. Kinosu, R. Ota, S. Katori, and K. Tanaka. 1955. Chemical studies on the red muscle ("Chiai") of fishes. III. Comparative studies of the amino acid contents in the protein of the ordinary and the red muscle of fishes by microbiological assay. Nippon Suisan Gakkaishi 20: 941–945.

The concentrations of 17 amino acids in the protein extracted from ordinary and red muscle of *Scomber japonicus*, and other fish were estimated microbiologically. The distribution of amino acids in the muscle protein of these fish was relatively uniform, and was independent of the kind of fish or muscle. Slight differences in distribution are discussed. The protein of the red and ordinary muscle of these fish may be considered to be as rich in the essential amino acids as other animal flesh.

101 Mel'nikova, O. M., and N. M. Khalina. 1956. Changes of fat in frozen mackerel during storage. Izv. Tikhookean. Nauchno-Issled. Inst. Rybn. Khoz. Okeanogr. 42: 299–302.

Hydrolysis and oxidation of fat occur vigorously in mackerel stored at −8 to −10 C, but not at −40 to −50 C. Heat has very little effect on extent of hydrolysis of glycerides during sterilization, but decomposes unstable peroxides to hydroxy acids and aldehydes. This explains the increase in organoleptic defects during the canning of fat fish.

102 Merson, M. H., W. B. Baine, E. J. Gangarosa, and R. C. Swanson. 1974. Scombroid fish poisoning. Outbreak traced to commercially canned tuna fish. J. Am. Med. Assoc. 228: 1268–1269.

In February 1973, scombroid fish poisoning occurred in 232 persons who had eaten from either of two lots of commercially canned tuna. Cases occurred in four states, with no reported hospitalizations or deaths. Patients became ill about 45 min after eating the fish; symptoms lasted about 8 h. Contaminated fish contained histamine levels of 68–280 mg/100 g fish muscle.

103 Miyake, M., and A. Tanaka. 1969. Studies on fish meat jellies (fish sausage). IX. Relationship between pH of fish meat paste and elasticity of fish meat jellies. Nippon Suisan Gakkaishi 35: 311–315.

A method for measuring elasticity of "Kamabokos" which gives good correlation with jelly strength measurements is described. Pastes of salted fish meat were examined and compared with organoleptic evaluation after pH adjustments from 5.90 to 8.75. Optimum pH values for desired physical characteristics were 6.2–6.7 for dark flesh fish (bluefin tuna, mackerel, and yellowtail), 7.0–7.5 for white flesh fish (flatfish, isaki, frozen Alaska pollack, Japanese seabass), and 7.0–7.2 for horse mackerel.

104 MURATA, K., AND K. OISHI. 1952. Fundamental examination for studying fish meat. II. A new method for estimating the putrefaction of fish meat. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 3: 128–141.

Data are given for the development of ammonia at 37 C in salted mackerel dried to various concentrations of salt and moisture. A graph is given relating this to storage life.

105 NAGASAKI, S., AND T. YAMAMOTO. 1954. Studies on the influences of salt on microbial metabolism. III. On the relation of salt concentration to the putrefaction of fish muscle and to ripening of "Ikashiokara." Nippon Suisan Gakkaishi 20: 613–616.

Salt in an amount that saturates the water contained in fish muscle is usually enough to ensure preservation of the fish. This relation is affected by drying the fish. The optimum salt concentration for the preparation of "ikashiokara" is 20% (at the optimum temperature of 20 C). Figures are given to show the changes in amino nitrogen and volatile basic nitrogen in mackerel muscle during drying, and during pickling with various amounts of salt, and in "ikashiokara" (prepared with various amounts of salt) during its ripening at 20 and 30 C. The development of the characteristic flavor of "ikashiokara" is apparently not due to changes in the relative concentrations of different amino acids during ripening.

106 NAKANO, T. 1961. Studies on the physiological chemistry of phosphorus compounds in fish muscle. VIII. The effect of urethane on phosphorus compounds in the muscle of mackerel. Nippon Suisan Gakkaishi 27: 1095–1099.

The muscles of mackerels treated with 0.5% urethane for 2.0 min, 1.0% urethane for 1.5 min, and 2.0% urethane for 1.0 min contained 20.8–22.1 mg% more of 7′P in ordinary muscle and 7.0–9.7 mg/100 g more of 7′P in dark muscle, respectively, than the control. There was little difference in CP content. Vigorous postmortem degradation of 7′P and CP in the fish narcotized with urethane began a few hours later than that in the fish which were numbed with low temperatures such as 0 C and −20 C, and lasted longer. There was little difference between the mackerel numbed with cold and the control.

107 NASEDKINA, E. A., AND YU. I. KAS'YANENKO. 1971. Free amino acid content of canned Pacific Ocean mackerel. Rybn. Khoz. (Moscow) 11: 73–74.

The free amino acid level in mackerel meat, especially of histidine, arginine, cystine, and serine, increased during preserving due to the increased temperature during meat sterilization. Preserved meat from freshly caught and aging mackerel had similar free amino acids content.

Preserved meat from aged mackerel had ~10% higher free amino acids content, especially arginine, serine, glycine, and threonine. Preserved meat of fresh and aging mackerel had good qualities, while meat preserved from aged mackerel had an unpleasant taste, due to the histamine (15–20 mg/100 g) and other extractable N-containing substances.

108 NICKERSON, J. T. R., S. A. GOLDBLITH, AND B. E. PROCTOR. 1950. A comparison of chemical changes in mackerel tissues treated by ionizing radiation. Food Technol. 4: 84.

Experiments were made to determine the relative importance of enzymic and bacterial changes in the spoilage of mackerel. Whole fish and some fillets were stored in ice and paired fillets were irradiated and then stored in ice. Organoleptic tests, bacteriological counts, and chemical determinations (trimethylamine, amino nitrogen, pH, peroxide, free fatty acid, and hydrogen sulphide) were carried out at the beginning of the experiment and after 2, 4, 6, and 8 days. Bacterial action did not take place in the flesh of whole, noneviscerated fish until the intestine broke; but before this occurred, quality had deteriorated greatly and the fish was not considered edible. Enzymic action (autolysis) was greater in whole, noneviscerated mackerel than in either irradiated (sterile) or nonirradiated (unsterile) fillets under the same conditions.

109 NISHIMOTO, J. 1962a. Changes in the amount of extractable nitrogen compounds in frozen fish muscle during storage. Kagoshima Daigaku Suisan Gakubu Kiyo 11: 152–157.

Frozen mackerel (*Scomber japonicus*) were stored at −10 or −20 C for 6 mo. During storage, extractable N compounds of the meats were determined at varying times. The amounts of mono- and diamino compounds and of total N in extracts from the meats progressively decreased in early periods of storage, and became constant after 2 or 3 mo. Mono- and diamino compounds showed scarcely any change during storage. Extractable N content was not influenced by storage temperature. No relation was found between the amino-N content and flavor of the meat.

110 NISHIMOTO, J. 1962b. The deterioration of frozen fishes during storage. Kagoshima Daigaku Suisan Gakubu Kiyo 11: 41–64.

Mackerel (*Scomber japonicus*) were frozen at −21 C and stored at −10 or −20 C for 6 mo. During storage, keeping quality was studied three ways: organoleptically, by protein solubility, or histology. It was suggested that the protein denaturation found was correlated with the presence of fatty acids and oxidized lipids. Drip quantity was correlated better with protein denaturation than with histologically determined denaturation.

111 NJAA, L. R., F. UTNE, G. BOGE, AND O. R. BRAEKKAN. 1968. Amino acid composition and the protein value of four selected fish meals for the young chick. Fiskeridir. (Norw.) Skr. Ser. Teknol. Unders. 5: 12 p.

Fish meals produced from different raw materials, winter herring, North Sea herring, scad, and mackerel were tested as supplements to a basal plant-protein chick diet. The fish meals were also analyzed for amino acids, vitamins, and the common chemical constituents. The four meals were equally well utilized by the young chick at three different protein levels and the supplementation of the fish meal proteins with 1% methionine was without any effect. Amino acid compositions of the four meals were very similar, the mackerel meal and the scad meal showing higher histidine values than the two herring meals. Mackerel meal was highest in riboflavine, nicotinic acid, and vitamin B_{12}. Scad meal was highest in thiamine. The two herring meals and the mackerel meal were chemically similar, but scad meal was higher in ash and Ca.

112 NOGUCHI, E., AND M. BITO. 1949. Studies on the preservation of fish. III. The preservative power of acidified ice. Nippon Suisan Gakkaishi 15: 75–77.

Mackerel was treated with acidified ice, and the effect of the ice on keeping quality was examined. It was found that, at 20–23 C, the start of putrefaction could be delayed for about 10 h longer than in fish treated with ordinary ice.

113 NOGUCHI, E., AND M. BITO. 1953. On the seasonal variations of the liver weight and oil content of mackerel. Nippon Suisan Gakkaishi 19: 525.

The weight of the livers of female mackerel increased to a maximum at spawning and then rapidly diminished; the liver weight in male fish was more constant. The vitamin A content of the liver oil varied with season, showed a maximum in June–July.

114 NOGUCHI, S., AND J. J. MATSUMOTO. 1970. Control of the denaturation of fish muscle proteins during frozen storage. I. Preventive effect of monosodium glutamate. Nippon Suisan Gakkaishi 36: 1078–1087.

The effect of Na glutamate on the frozen-storage denaturation of an isolated actomyosin prepared from carp was studied; 0.3 M Na glutamate was slightly better than M glucose in preventing denaturation measured by solubility, viscosity, ATPase activity, and ultracentrifugal patterns. No significant differences were found between results of experiments in 0.6 M KCl and 0.05 M KCl. Addition of urea promoted denaturation. In 0.6 M KCl, Na glutamate had an optimum effect at 0.025 M, Kamaboko jelly made of frozen mince with added Na glutamate was better than the control in keeping qualities as measured by jelly strength, folding test, and amount of water and soluble proteins.

115 NOGUCHI, S., AND J. J. MATSUMOTO. 1971. Control of the denaturation of fish muscle proteins during frozen storage. II. Preventive effect of amino acids and related compounds. Nippon Suisan Gakkaishi 37: 1115–1122.

By using an in vitro model test system, a determination was made of the preventive effect of 29 substances on the freezing denaturation at −30 C for 4–8 wk. The rate of denaturation was followed by estimating the solubility, viscosity, and ATPase activity, as well as superprecipitation. Additives with a significant effect were: glutamate, aspartate, cysteine, β-alanine, γ-aminobutyric acid, cysteate, acetylglycine, and EDTA. In tests of the combined use of two kinds of amino acids, some synergistic effect was noted with lysine and threonine, with lysine and serine, and with lysine and cystine. No effect was found in any combination with glutamate. The results suggested that the protective effects of the substances were closely related to their functional groups, their spacial structure, and other physicochemical properties.

116 NOGUCHI, S., AND J. J. MATSUMOTO. 1975a. Studies on the control of denaturation of fish muscle proteins during frozen storage. III. Preventive effect of some amino acids, peptides, acetylamino acids and sulfur compounds. Nippon Suisan Gakkaishi 41: 243–249.

Proline, cysteine, glutamylcysteinylglycine, and acetylglutamine had a marked preventive effect on the denaturation of carp actomyosin stored in vitro in 0.6 M KCl for 4–8 wk at −30 C. Final concentration of the additives was 0.1 M at pH 7. The rate of denaturation studies were followed by estimates of solubility and superprecipitation. Other compounds had moderate or no effect. The additive molecules might be bound to protein molecules by SS bonding. This would leave the charged CO_2H and NH_2 groups intact and thus increase hydration.

117 NOGUCHI, S., AND J. J. MATSUMOTO. 1975b. Control of denaturation of fish muscle proteins during frozen storage. IV. Preventive effect of carboxylic acids. Nippon Suisan Gakkaishi 41: 329–335.

Malonic, maleic, lactic, malic, tartaric, gluconic, glycolic, methylmalonic, dimethylmalonic, and tartaric acids were each effective in preventing or retarding fish muscle actomyosin denaturation in frozen buffered solutions (pH 7). Other common carboxylic acids had less, or no, effects.

118 OISHI, K., S. OKA, AND M. HIRAOKI. 1971. Food hygiene studies on Anisakis larva. I. Numerical method for detecting larvae in the muscle and viscera of fish. Nippon Suisan Gakkaishi 37: 186–191.

Anisakiasis in man is caused by penetration of Anisakis worms into the walls of the gastrointestinal tract. Anisakis worms are parasitic in the muscle and viscera of sea fish. The disease may become prevalent among people who eat raw fish. Four methods of detecting Anisakis larvae were examined: glass pressure method; preservation at fixed temperature (autolysis including putrefactive decomposition); enzymatic digestion using commercial preparations; digestion by bacterial protease secreted for 5–6 days at 37 C. Mackerel, jack-mackerel, flatfish, squid, prawn, short-necked clams, and surf clams were used as test animals. The worms were easily detected in ordinary muscles by the glass pressure method. With dark muscle, detection by this method was difficult, because the worms are not transparent and therefore not reflective under light. With viscera, especially the digestive tract, the same difficulty was found with this method. Autolysis including bacterial decomposition was prefered for estimation of worms in the viscera. Neither enzymatic digestion by commercial preparations nor bacterial decomposition were useful for worm detection.

119 OLSEN, I. A. 1955. Freezing fish in alginate jelly. Food Manuf. 30: 267–270.

While most fish can be successfully preserved by deep-freezing, fatty fish such as herring and mackerel tend to go rancid. A process for freezing fish in alginate jelly, developed by the Protan company in Norway, prevented oxidative rancidity in herring fillets and herring for bait, and also drying out and damage of the fish during thawing. Herring were milder in taste after storage in the jelly and lost their characteristic unpleasant odor when fried. Freezing time was reduced by 20–25%, compared with an ordinary freezing process, and the setting time of the jelly could be regulated. The Protan method, originally developed for herring and mackerel, has been extended to shrimps, sardines, brisling, and whale meat, with similar success.

120 ONO, T. 1935. Chemical changes in fish body fats in cold storage. Nippon Suisan Gakkaishi 3: 255.

Shows that hydrolysis of fat during storage (at a temperature of −13 C) of mackerel and sardines is due to the action of the enzyme lipase. Observations of the action of lipase at low temperatures showed that the enzyme acts mainly on unsaturated glycerides. Phosphatides (lecithin) may also be hydrolyzed by means of a lipolytic enzyme. Freezing of fish in air or brine or glazing of fish had no effect on chemical changes in the fat.

121 ONO, T., F. NAGAYAMA, AND T. SASAKI. 1957. Biochemical studies on the vitamin A in fish viscera. IV. Lipoxidase in liver and dark muscle. J. Tokyo Univ. Fish. 43: 49–57.

The oxidation of β-carotene in the presence of linoleic acid by extracts of fish liver and muscle was attributed to a lipoxidase. Tissues of the frigate mackerel showed higher activity than those from the Pacific mackerel. The optimum pH of the reaction was 6.8. The temperature optimum for the frigate mackerel extracts was 15 C, while extracts from the Pacific mackerel exibited optimums at both 15 and 45 C.

122 ONO, T., F. NAGAYAMA, AND T. YAMADA. 1958–9. Fat metabolism in fish. II. Contents of fat and cholic acid in the liver of Pacific mackerel. Nippon Suisan Gakkaishi 24: 862–864.

In pacific mackerel livers, the fat content was 5.9–23.6% and cholic acid content was 31.1–157.5 mg/100 g. The cholic acid content was independent of sex, size, season, and fat contents in liver and muscle, but it was inversely proportional to liver size. It was suggested that the absolute content of liver cholic acid was nearly constant and had no relation to fat assimilation.

123 OSADA, H. 1969. The determination of metals in foods by atomic absorption spectrophotometry. IV. Determination of copper. J. Jpn. Soc. Food Nutr. 22: 548–551.

Only traces of Cu were found in samples of canned tuna and mackerel.

124 OSHIRO, Z. 1962. Carboxy peptidase of the pyloric caeca of mackerel, *Scomber japonicus*. Kagoshima Daigaku Suisan Gakubu Kiyo 11: 111–151.

The preparation and some kinetic properties of the enzyme are described. A close combination of Co^{++} with the active center is postulated.

125 POTTINGER, S. R. 1951. Effect of fluctuating storage temperatures on quality of frozen fish fillets. Commer. Fish. Rev. 13: 19–27.

Fillets of mackerel were wrapped in cellophane and stored at −23, −18, and −9 C, and at temperatures fluctuating, in cycles of 1, 3, or 4 days between −23 and −18 C, and between −18 and −9 C. They had a storage life of about 2 mo at −9 C, and about 4 mo at −18 and −23 C. There was no adverse effect on the quality of the frozen fish due to fluctuating temperature appears more likely to be the deciding factor.

126 RAO, S. V. R., AND V. S. KHABADE. 1968. Studies on the artificial drying of salted mackerel. J. Food Sci. Technol. (Mysore) 5: 123–126.

Salt-cured mackerel of moisture content 57–60% can be dried to 30–38% moisture in 12 h in a batch process cross-flow air dryer. Air at 45 C and 50% RH is used. The fish show signs of cooking at 50 C. Fresh mackerel need to be dried for twice as long to reach the 17.6% moisture content suitable for storage.

127 SAITO, T., K. ARAI, AND T. YAJIMA. 1959. Organic phosphates in muscle of aquatic animals. VII. Changes in the purine nucleotide contents of red lateral muscle of fish. Nippon Suisan Gakkaishi 25: 573–575.

The amounts of purine compounds in dorsal and red lateral muscles of refrigerated mackerel were determined. The total amounts were larger in the dorsal than in the red muscle. Decomposition of the purines was faster in the red muscle than in the dorsal, probably because of differences in 5′-nucleotidase activities.

128 SAITO, K., AND M. SAMESHIMA. 1958. Biochemical change in fish muscle. VIII. The proteolytic activity of fish muscle extracts. Nippon Suisan Gakkaishi 24: 201–204.

The proteolytic activities of water and 0.2 M KCl extracts of carp, mackerel, and shark muscles were nearly identical to each other, but that of 0.5 M KCl extract was smaller. The actomyosin fraction showed no proteolytic activity. The optimum pH of the extracts of these fish muscles was at pH 3.5–5.0, independent of species and differences of ordinary and red muscles. The optimum temperature was around 35 C, at pH 3.5 and in a reaction period of 10 h; at 40 C the activity was slightly less and at 50–60 C the enzymic activity was inactivated in 5 min. The enzyme was still active at 0 C.

129 SAKAGUCHI, M., AND W. SHIMIZU. 1964. Muscle of aquatic animals. XLIV. Amino acids, trimethylamine oxide, creatine, creatinine, and nucleotides in fish muscle extractives. Nippon Suisan Gakkaishi 30: 1003–1007.

Muscle of dark-fleshed fishes was rich in extractive N in which histidine N was predominant. In white-fleshed fish, the muscle extractive N was low and creatine content was larger than histidine. In elasmobranchs urea was the major component of the extractive.

130 SAKAGUCHI, M., AND W. SHIMIZU. 1965. Muscle of aquatic animals. XLV. Variation with season and growth in the nitrogenous extractives of mackerel muscle. Nippon Suisan Gakkaishi 31: 72–75.

The muscle of the mackerel caught in the winter season contained more nitrogenous extractive than that of mackerel caught in the spring. The contents of histidine and creatine were also larger in the extractives from the former. The small-sized mackerel contained less nitrogenous extractive and had a smaller histidine content than larger ones.

131 SANAHUJA, C., AND D. SEOANE RIOS. 1956. Determination of essential amino acids in the proteins of meat of mammals (cattle, sheep, pigs) and edible fish of Argentina. III. Phenylalanine and arginine. An. Bromatol. 8: 191–196.

The eight species of fish examined, including *Scomber scombrus*, contained an average 4.63% phenylalanine and 6.44% arginine. There were no marked differences in the content of either amino acid in the various meats and fish examined.

132 SEN, D. P., AND N. L. LAHIRY. 1964. Studies on the production of better quality salt-cured and sun-dried mackerel (*Rastrelliger canagurta*). Food Technol. 18: 107–110.

Fish cured in a mixture of salt, Na benzoate, Na-acid-phosphate, Na-bicarbonate, Na-hexametaphosphate, and ascorbic acid, and then dipped in K-sorbate solution prior to drying kept well for 6–8 mo at room temperature.

133 SENO, Y. 1964. Processing and utilization of mackerel, p. 147–151. *In* R. Kreuzer [ed.] Fishery products. FAO; Fishing News (Books) Ltd., London.

134 SHATENSTEIN, V. 1970. New fish products. Rybn. Khoz. 46: 51–53.

New products from mackerels (containing nutmeg, dill, cinnamon, bay leaves) are described. Individual production processes are described, listing the differences in handling frozen, fresh, chilled and salted fish, methods of preparing spices, recipes for spice mixtures, and spicing of barrel packed fish. The ripening of products takes 15–20 days at 5–7 C and the mixture must be stirred at least 3 times. The temperature for additional storage should be 2 to −6 C. In taste evaluation examinations the new products were highly acceptable.

135 SHENDERYUK, V. I., AND O. N. SHUMAROVA. 1969. Proteinases of the internal organs of Atlantic fish. Izv. Vyssh. Uchebn. Zaved. Pishch. Tekhnol. 2: 25–26.

The authors investigated the qualitative composition of proteinases of the internal organs of Atlantic fish species and compared their activity. The proteolysis of the internal organs was investigated at various pH values in buffer solutions. In the fish organs, trypsin and pepsin were identified. Proteolysis is fastest in the mackerel and slowest for the herring, which is due to the varying enzymatic activity at natural pH. For each of the fish a different optimum pH value for proteolysis was found.

136 SHEWAN, J. M. 1951. The chemistry and metabolism of the nitrogenous extractives in fish. Biochem. Soc. Symp. 6: 28–48.

The nitrogenous extractives form 9–14% of the total nitrogen in the muscle of flat fish, cod, haddock, etc., 14–18% in the herring group, and 34–38% in skate, dogfish, etc. The extractives may be divided into volatile bases (ammonia and methylamine), trimethylammonium bases (trimethylammonium oxide, betaine), guanidine derivatives (creatine, arginine), imidazole derivatives (histidine, carnosine, anserine), and a miscellaneous group (urea, amino acids, purine derivatives). Details are given of variations in the content of trimethylammonium oxide in different species, at different seasons, in different regions, and of the distribution of betaines and creatine in different species. Recent work on the imidazole derivatives shows that histidine is found in freshwater fish, and in marine elasmobranchs and fish of the mackerel tribe; carnosine in

sturgeon and possibly also in cod; and anserine in haddock and whiting. Reference is made to the importance of urea in the metabolism of elasmobranchs. The decrease of trimethylammonium oxide and increase of free methylamines and ammonia in fish undergoing spoilage is described.

137 SHEWAN, J. M. 1955. The nitrogenous extractives from fresh fish muscles. III. Comparison of several flat fishes and members of the herring-mackerel group. J. Sci. Food Agric. 6: 99–104.

Aqueous-alcoholic extracts of the muscle of six species of flat fish and four species of pelagic fish were fractionated by displacement chromatography on ion exchange resins. Creatine, creatinine, and trimethylamine oxide were common to all. The amino acids in extracts of flat fish were rather similar to those previously reported for gadoid fish. The pelagic fish differed in containing large amounts of histidine, and no carnosine or anserine, or the constituent amino acids of the latter, methylhistidine and β-alanine.

138 SHEWAN, J. M., AND J. LISTON. 1955. A review of food poisoning caused by fish and fishery products. J. Appl. Bacteriol. 18: 522–534.

139 SHIMIZU, W., Y. KUROKAWA, AND S. IKEDA. 1953. Studies on muscle of aquatic animals. XVII. Imidazole compounds in fish muscles, with special reference to the taste of red-muscle fishes. Kyoto Daigaku Shokuryo Kagaku Kenkyusho Hokoku 12: 40–48.

The extract of red muscle contained a large amount of histidine, and the content increased during storage at lower temperatures, parallel to the improvement in flavor. Yellowtail contained more histidine and had a better flavor than mackerel. Carnosine, which is present in small amounts in yellowtail and mackerel muscles, decreased during storage. When the fish muscle was kept at high temperatures, histidine rapidly disappeared, and the content of histamine increased. The increase of histamine was greater than the decrease of histidine, and this difference was more marked at lower temperatures. The amount of histamine formed paralleled the amount of volatile base evolved; at the lowest temperatures, the formation of histamine was delayed. This indicates that when fish flesh is preserved at low temperatures, putrefaction does not always cause poisoning. The formation of histamine may be due largely to bacterial action and, to some extent, to autolysis of meat. *See also* Kyoto Daigaku Shokuryo Kagaku Kenkyusho Hokoku 10: 78–82 (1952).

140 SHIMIZU, W., S. IKEDA, AND Y. KUROKAWA. 1953. Studies on muscles of aquatic animals. XVIII. L-histidine decarboxylase. Kyoto Daigaku Shokuryo Hokoku 12: 49–56.

The activity of L-histidine decarboxylase in fresh mackerel and yellowtail flesh was optimal at pH 7.5 and at 45 C; in the viscera, the optimal pH was 6.5. In the course of spoilage of the fish flesh, the optimal pH gradually shifted to the acid side, finally to pH 4.5, and the optimal temperature was 32 C. These findings indicate that autolytic as well as bacterial enzymes are present in fish flesh, and that histamine is produced not only by bacterial but also by autolytic action. During preservation, some powerful enzyme in the entrails of these fish greatly influenced the formation of histamine in the flesh attached to the entrails.

141 SHIMIZU, W., AND S. HIBIKI. 1954. Studies on putrefaction of aquatic products. XVI. Consideration on differences in putrefaction for various kinds of fish. Nippon Suisan Gakkaishi 20: 392–395.

Juices extracted from the muscles of yellowtail and mackerel underwent spoilage at much the same rate, producing similar amounts of volatile base and histamine. The more rapid production of volatile base, trimethylamine, and histamine that occurs in mackerel muscle, as compared with yellowtail muscle, must depend on the nature of the muscles rather than of their extractives. Addition of raw or cooked yellowtail extractives to mackerel muscle did not delay spoilage, and minced mackerel muscle tended to resemble minced yellowtail muscle in spoilage behavior, suggesting that physical rather than chemical factors are involved.

142 SHIMIZU, Y., AND W. SIMIDU. 1958. On the extractability of fish muscle proteins. Mem. Coll. Agric. Kyoto Univ. Fish. Ser. Spec. No. p. 68–76.

A study of conditions affecting the extractability with NaCl of soluble proteins, especially actomyosin, the primary gel in kamaboko. Lizard fish, striped bass, and chub mackerel were used in experimenting. Homogenizing fish muscle with ice water in a blender at 0 C avoided froth; extraction and centrifuging were followed by assay of soluble and insoluble protein nitrogens. Viscosity of the extracts was exponentially related to the velocity gradient. Optimum extraction occurred in 2–3 h using 0.4–0.6 M NaCl at pH. 6.5–7.0, yielding >90% of the extractable protein, 70% of which could be precipitated as actomyosin. Using 1.5 M NaCl, only 20% of the soluble protein was actomyosin. Thixotropism and turbidity were observed in extracts with 0.6, but not with 1.5 M NaCl. Extractable proteins, probably actomyosin, decreased with cold storage of the fish.

143 SHIMIZU, W., AND S. HIBIKI. 1954. Studies on putrefaction of aquatic products. XVII. Consideration of differences in putrefaction for various kinds of fish (2). Influence upon tenderness of flesh. Nippon Suisan Gakkaishi 20: 717–719.

In the putrefaction of yellowtail, mackerel, and bonito, the changes in tenderness, pH, and contents of volatile base and trimethylamine, were similar for each fish. The production of histamine was least in yellowtail, although this fish had the highest content of histamine. The processes of putrefaction were not affected by pressing or crushing the fish.

144 SHIMIZU, W., S. HIBIKI, S. UENO, Y. SHIMIZU, M. FUJITA, K. ENDO, U. SHIMIZU, T. IKEUCHI, I. TAKAGI, H. TERASHIMA, AND A. NAGASAKI. 1962. Fish sausage. VI. The heating conditions in the presence of antiseptics. Kyoto Daigaku Shokuryo Kagaku Kenkyusho Hokoku 25: 1–9.

Cooking of fish meat, sausage made from flying fish and mackerel meat, pork fat, salt, vegetable oil, starch, Na glutamate, and spices in the presence of 20 ppm. Neofuraskin (a mixture of nitrofurylacrylamide and nitrofurazone) above 85 C for 60 min increased the preservable period but decreased the palatability after 7 days. Aureomycin and sorbic acid were ineffective as antiseptics. There were no significant relations between microbial count, acid amount, and the amount of volatile amines during the progress of the deterioration of fish sausage.

145 SIMIDU, W., AND T. KIRIYAMA. 1954. Studies on the putrefaction of aquatic products. XI. Effect of antiseptics on fish muscles. Nippon Suisan Gakkaishi 20: 33–35.

Curves show the effects of toluene, chloroform, or thymol in delaying spoilage (measured by increase in volatile basic N) in mackerel and yellowtail at various temperatures. Addition of thymol to toluene or chloroform markedly increased the antiseptic effect.

146 SIMIDU, W., AND S. HIBIKI. 1954a. Studies on putrefaction of aquatic products. XII. On putrefaction of bloody muscle. Nippon Suisan Gakkaishi 20: 206–208.

More volatile base was formed during spoilage in the "bloody" muscle of mackerel, yellowtail, and bonito, than in ordinary muscle. Trimethylamine was apparently formed before ammonia. Decrease of histidine and increase of histamine were less in "bloody" than in ordinary muscle.

147 SIMIDU, W., AND S. HIBIKI. 1954b. Studies on putrefaction of aquatic products. XIII. Comparison of putrefaction of different kinds of fish. (1). Nippon Suisan Gakkaishi. 20: 298–301.

Large amounts of histamine were produced in the early stages of spoilage of mackerel, but only small amounts in yellowtail; in both cases little trimethylamine was produced, and detection of the early stages of spoilage by taste was difficult.

148 SIMIDU, W., AND S. HIBIKI. 1954c. Studies on putrefaction of aquatic products. XIV. Comparison of putrefaction of different kinds of fish. (2). Nippon Suisan Gakkaishi 20: 302–304.

The production of volatile base, trimethylamine, trimethylamine oxide, and histamine proceeded at much the same rate in minced muscle of yellowtail, mackerel, sardine, and bonito, stored at the same temperature. Variations appeared to be due to differences in extent of bacterial contamination, and in length of time after catching.

149 SOHN, B. I., J. H. CARVER, AND G. F. MANGAN. 1961. Composition of commercially important fish from New England waters. I. Proximate analyses of cod, haddock, Atlantic ocean perch, butterfish, and mackerel. Commer. Fish. Rev. 23: 7–10.

The protein, oil, and moisture content of these fishes were determined. Analysis of variance tests indicated that in almost all cases the variation in proximate components that exist within a species is related to the time of year.

150 SOREMARK, R. 1967. Vanadium in some biological specimens. J. Nutr. 92: 183–190.

North Sea mackerel was relatively rich in vanadium; soft tissues contained 0.26×10^{-2} (0.15–0.36) ppm (wet wt), and bone contained 2.0×10^{-2} (1.1–4.1) ppm.

151 SPRAGUE, J. B., AND J. R. DUFFY. 1971. DDT residues in Canadian Atlantic fishes and shellfishes. J. Fish. Res. Board Can. 28: 59–64.

DDT residues were average or less than average in lobsters, five species of molluscan shellfishes, and seven species of finny fishes from estuarial and coastal waters of New Brunswick and Prince Edward Island, compared with the same or similar species elsewhere in North America and northern Europe. Mackerel had the highest residues, averaging 0.38 ppm of DDT or 0.54 ppm DDT plus metabolites. These levels do not seem to be an immediate danger to the fish. In terms of human diet, residues in mackerel are as high as those in some beef. The other species averaged 0.1 ppm or less of total DDT residue in the whole body or muscle, usually much less. This is relatively low by present day findings. Viscera of salmon, cod, and hake had 6–15 times higher concentration of DDT residues than did muscle. Flounder viscera had no more residue than did muscle, whereas lobster eggs had 9 times as much as muscle. None of the four sampling locations produced consistently higher residues than the others.

152 STANSBY, M. E., AND J. M. LEMON. 1941. Studies on the handling of fresh mackerel, *Scomber scombrus*. U.S. Fish. Wildl. Serv. Res. Rep. 1: 1–46.

The fat content of the mackerel varies with the season, from a minimum of approximately 2% in the spring to a maximum of 20% or more in the late summer and fall. Spoilage in the mackerel is much more complicated than in nonfatty fish. Evisceration greatly increases the storage life of this species. Thus, eviscerated mackerel will keep in crushed ice for 7–10 days, while floated mackerel will keep only about 4 days in good condition. Decomposition of the flesh and its detection by organoleptic and chemical methods are described in detail. The presence of "red feed," *Calanus finmarchicus*, in the stomach greatly accelerates decomposition. Chemical tests for H_2S and rancidity of the fat are of value.

153 STOLOFF, L. S., J. F. PUNCOCHAR, AND H. E. CROWTHER. 1948. Curb mackerel fillet rancidity with new dip-and-coat technique. Food Ind. 20: 80.

Frozen mackerel fillets cannot be kept in commercial storage for more than 3 mo. To extend this period, the authors carried out tests which they report in detail. The fillets were dipped in a viscous solution containing an antioxidant. The material selected as a coating was an aqueous solution of refined Irish moss extractive. Gallic acid, ascorbic acid, or nordihydroguaiaretic acid (NDGA) in cottonseed oil appeared to delay spoilage until the 7th or 8th mo.

154 SUGIMURA, K., H. TIARA, N. HOSHINO, H. EBISAWA, AND T. NAGAHARA. 1954. The amino acid content of fish muscle protein. Nippon Suisan Gakkaishi 20: 520–524.

The muscle proteins of bonito, horse mackerel, turbot, and two species of squid, were examined by microbiological assay to determine their contents of 16 amino acids; the results are discussed in connection with previously reported values.

155 TAKAHASHI, T., T. MORISHITA, AND S. TACHINO. 1964. Proteolytic enzymes of the liver in marine animals. Rep. Fac. Fish. Prefect. Univ. Mie 5: 137–144.

The proteolytic activity of the liver of *Scomber japonicus* had an optimum pH of ~2.6, and optimum temperature of 45 C. The activity was slightly accelerated by the addition of NaCN and cysteine.

156 TAKAMA, K., K. ZAMA, AND H. IGARASHI. 1971. Changes in the flesh lipids of fish during frozen storage. II. Flesh lipids of several species of fish. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 22: 290–300.

The minced flesh of five species of fish was stored at –20 C for 100–120 days, and samples were withdrawn at intervals throughout the storage period. The properties of lipids extracted from these samples were compared. The rates of free fatty acid production in minced flesh (μmol/day/100 g) were approximately as follows: Alaska pollack 12.0, mackerel 8.0, yellowtail 3.1, and northern blenny and flying aquid 2.0. From these findings, lipid degradation was attributed to the influence of hydrolysis and oxidation.

157 TAKENAKA, Y. 1962. Insulin from fish, notably the mackerel and tuna. Prod. Pharm. 17: 421–423.

A review with 29 references.

158 TANIKAWA, E., M. AKIBA, AND T. MOTOHIRO. 1952. Studies on the manufacture of canned mackerel. I. Comparison of chemical components of meat of mackerel caught, respectively, in the Japan sea and in the Pacific Ocean off the Hokkaido coast. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 3: 1–6.

The contents of water, ash, ether-soluble fat, total protein, nonprotein nitrogen fractions, and the acid, saponification, and iodine values of the extracted oils were determined.

159 TANIKAWA, E., S. AKIBA, Y. INOUE, M. AKIBA, AND T. MOTOHIRO. 1952. Studies on the manufacture of canned mackerel. II. Relation between freshness of mackerel meat and the quality of the canned product. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 3: 7–12.

The mackerel were left at 15 C, and spoilage allowed to develop. After 12–30 h, samples were canned and stored at room temperature for 1 mo. Fresh fish or fish stored for less than 12 h was of good quality when canned, and the flesh did not crumble; but with fish canned after storage for more than 12 h, there was considerable crumbling of the flesh. If the raw fish contained more than 20 mg/100 g of volatile base nitrogen, canned mackerel of good quality could not be produced. More 'curd' (coagulated protein) was formed on the surface of the contents of the can when fresh fish was used than with stale fish. The method of seaming the cans did not affect the quality of the canned mackerel.

160 TANIKAWA, E., Y. INOUE, S. AKIBA, M. AKIBA, AND T. MOTOHIRO. 1952. Studies on the manufacture of canned mackerel. III. Relations between quality of canned mackerel and the leaving time before retorting (sterilization) after the cans have been seamed. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 3: 13–17.

The mackerel was packed in 1–lb cans, and the cans were seamed after exhausting in steam or by vacuum seamer, then left for 0, 20, 40, 60, 80 or 100 min before sterilization. Cans which had been sterilized without delay, and control cans, which had been allowed to stand for the same times but were not sterilized, were opened the same day; the other cans were stored for a month at room temperature (15–25 C), and the quality of the products was then examined. Results showed that the longer the cans were allowed to stand before sterilization, the more the quality of the canned product deteriorated. The packed and seamed cans should not be allowed to stand for more than 40 min (or 60 min at most) before sterilization.

161 TANIKAWA, E., Y. INOUE, AND T. NUMAKURA. 1952. Studies on the manufacture of canned mackerel. IV. Studies on deformation of shape of the content in the canned mackerel. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 3: 18–22.

To produce canned mackerel in which the shape can be maintained, and which is resistant to shock, it is recommended that the fish, in the cans, should be precooked at 100 C in steam for 20 min, and 30% brine should be added to the cans before processing; also, the backbone of the fish may be removed, as the processing time can then be shortened, and the fish may be immersed in 18% brine for 20 min before processing. Extent of crumbling depended on the freshness of the raw material.

162 TANIKAWA, E., Y. INOUE, M. AKIBA, AND T. NUMAKURA. 1952. Studies on the manufacture of canned mackerel. V. Studies on the formation of curd in canned mackerel. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 3: 23–30.

Studies on the formation of 'curd' (coagulated protein) on the surface of the brine in canned mackerel are described. The curd appears to be formed during the exhausting of the cans in steam or during processing. Tests with pieces of mackerel, immersed in brines of different concentrations for 45 min, showed that the amount of protein dissolved in the brine increased with concentration of the brine, reaching a maximum in 5% brine. Determination of heat-coagulable material in the brine extracts of the muscle indicated that a 10–11% brine was the most suitable for removing the maximum amount of heat-coagulable, brine-soluble protein from mackerel flesh. Practical application of these results to the canning of mackerel led to the conclusion that formation of curd can be prevented by treating the fish with 10–15% brine; the dressed fish should be cut into round slices, immersed in brine for 25–30 min, and washed before further treatment.

163 TANIKAWA, E., AND Y. INOUE. 1952. Studies on the manufacture of canned mackerel. VI. Studies on the cause of the springers of canned mackerel. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 3: 30.

To prevent the occurrence of bulged ends of the cans (springers), it is necessary to avoid packing the fish too tightly, so that air in pockets may escape during eshaustion, or to extend the time of exhaustion.

164 TANIKAWA, E., AND T. YAGI. 1954. Studies on the manufacture of canned mackerel. VII. The relation between the freshness degree of raw mackerel meat and the quality of canned boiled mackerel. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 5: 153–163.

Determinations of volatile basic nitrogen and pH were made on raw mackerel held at various temperatures for various periods, and the mackerel was then canned. Fish with a content of volatile basic nitrogen above 20 mg/100 g gave an unsatisfactory canned product. This content was reached after 80 h at 8 C, 17 h at 20 C, 9 h at 30 C, and 7 h at 37 C.

165 TEERI, A. E., M. E. LOUGHLIN, AND D. JOSSELYN. 1957. Nutritive value of fish. I. Nicotinic acid, riboflavine, Vitamin B_{12}, and amino acids of various salt-water species. Food Res. 22: 145–150.

Halibut, mackerel, salmon, swordfish, and tuna are better sources of nicotinic acid than is beef. Haddock roe, mackerel, smelts, clams, oysters, salmon, and tuna are equal to beef in riboflavine. The chromatograms of the hydrolyzed fish proteins showed a similar pattern of distribution for all species analyzed. Mackerel has an unusually high histidine content.

166 TOKUNAGA, T. 1964. Development of dimethylamine and formaldehyde in Alaskan pollock muscle during frozen storage. Suisan Cho Hokkaido Ku Suisan Kenkyusho Kenkyu Hokoku 29: 108–122.

During storage for 2–6 mo at −18 C, large amounts of DMA and HCHO were formed in Alaska pollock muscle, and lesser amounts in muscle of seven other species, including mackerel and Atka mackerel.

167 TOKUNAGA, T. 1970. Trimethylamine oxide and its decomposition in the dark muscle of fish. I. TMAO, TMA and DMA contents in ordinary and dark muscles. Nippon Suisan Gakkaishi 36: 502–509.

Measurements of trimethylamine oxide (TMAO), trimethylamine (TMA), and dimethylamine (DMA) in dark and light muscles of 16 species of fish were carried out. In varieties of so-called dark-fleshed fish such as mackerel, sardine, skipjack, etc., the dark muscles were rich in TMAO content, while in the light colored muscles the TMAO content was poor and variable. In each fish examined, the amount of TMA detected in the dark muscle was larger than that in the light muscle. Although a very small quantity of DMA was found in the light muscle of some kinds of fish, larger quantities of DMA were always observed in the dark muscle of all species examined. Formaldehyde was also detected in the dark muscle whenever DMA was found, and this may suggest the possible existence of enzyme(s) capable of producing DMA and formaldehyde from TMAO in the dark muscles of a rather wide variety of fish.

168 TOKUNAGA, T., AND M. NAKAMURA. 1962. Preservation of fish by furantoin. Hokusuishi Geppo 19: 66–70.

Keeping mackerel in ice water containing 15–20 ppm of furantoin (5-nitro-2-furfurylidene aminohydrantoin) prolonged preservation 3–4 days longer than in ice.

169 TOMIYAMA, T., Y. YONE, AND K. MIKAJIRI. 1957. Uptake of aureomycin chlorotetracycline by fish and its heat inactivation. Food Technol. 11: 290–293.

Determinations by a modified pad plate assay showed that chlorotetracycline, at 10 ppm in chilled sea water did not penetrate into the muscle tissue or round fish within the first 24 h, except in the case of small fish with incompletely developed scales, e.g. pilchard, common mackerel. The data suggest that in round fish chlorotetracycline prevents spoilage by inhibiting bacterial growth on the surface, thus preserving the integrity of the skin barrier, and delaying the penetration of bacteria into the flesh. The rate at which chlorotetracycline in bonito muscle was destroyed by heat increased rapidly with temperature of heating; the amount of residual chlorotetracycline was exponentially related to the duration of heating.

170 TOMIYAMA, T., AND T. SUGITANI. 1958. Effectiveness of tetracycline treatment on quality improvement of processed foods. I. Effect of chlortetracycline treatment on quality of salt sardine and salt mackerel, and change in residual chlortetracycline during the salting. Nippon Suisan Gakkaishi 24: 581–585.

When mackerel was salted in brine containing CTC at 4–12 C, the loss of CTC was linearly proportional to time, and after 13 days the residual amount was 20% of the original. CTC added to mackerel muscle homogenate containing 5% NaCl was destroyed gradually at room temperature, and when CTC was below 2 ppm, putrefaction started.

171 TOMIYAMA, T., AND Y. YONE. 1959. Effectiveness of dip in iced chlortetracycline (CTC)–containing sea water on keeping quality of mackerel aboard ship and determination of CTC residue on the fish. Nippon Suisan Gakkaishi 25: 290–293.

Mackerel were placed immediately after being caught in a fish hold which contained ice and chlortetracycline (CTC) sea water and kept for 6–7 days. Freshness and CTC residue were estimated after landing. A storage experiment at 3–7 C was carried out in an ice plant. When mackerel were held in about 3 ppm CTC sea water, the residues in the muscle and the skin were 0.09 and 1.25 ppm, respectively. The distribution pattern of CTC in muscle showed a sharp decrease in the residue within a 5 mm depth, and no CTC was found in the muscle deeper than 9 mm. When mackerel were stored in at 3–7 C after landing, the storage life of both the CTC-treated groups was 7 days as compared with 5 days for the control group. The formation of histidine in muscle during storage was greatly inhibited when the fish were dip-treated aboard ship.

172 TOMIYAMA, T., K. IKEURA, AND S. OYAMA. 1960. Spoilage of food. XI. Determination of volatile reducing substances of mackerel meat by steam distillation. Nippon Suisan Gakkaishi 26: 33–38.

The volatile reducing substances that occurred at the onset of putrefaction of fish meat were neutral and basic substances. $MgSO_4$-

treated, deproteined meat extract was distilled instead of the whole meat. Comparison of the data of volatile basic N, histamine, and bacterial count during loss of freshness of mackerel meat at low temperatures indicated that increases in volatile substances indicate the onset of putrefaction.

173 TOMIYAMA, T., AND K. KITAHARA. 1963. Inactivation of chlortetracycline in muscle tissue and the method for its stabilization. Nippon Suisan Gakkaishi 29: 463–468.

Addition of chlortetracycline (CTC) to mackerel meat brei was followed by a partial destruction of CTC, which was prevented by the presence of chelating agent or iso-Am gallate. Addition of the gallate to the brei caused discoloration to grey-black, indicating that the destruction of CTC was due to the action of Fe. CTC in the brei preserved at 0 C was promptly destroyed in 3 days; addition of antioxidants prevented the destruction, iso-Am gallate being more effective than butylated hydroxytoluene. When an aqueous solution of CTC at pH 7 was heated to 100 C to destruction, the presence of gallate or chelating agent did not influence the rate of decomposition. After preserving the CTC-brei for 3 days at 0 C the rate of CTC decomposition decreased rapidly, probably because the oxidation product of CTC or fats had sufficient antibacterial activity.

174 TSUCHIYA, Y., Y. SATO, Y. SUZUKI, T. NAKANO, H. KUDO, T. SASAKI, M. MURASE, AND Y. YAMAZOI. 1959. The influence of treatments immediately after catching on the quality of fish meat. I. Examination of killing and storing methods for keeping quality of mackerel, dace, and carp. Nippon Suisan Gakkaishi 25: 373–380.

The best method found was to stun fish by a blow on the head, decapitate, and eviscerate. Round fish killed by exposure to air after catching were the worst. Killing by cutting the tail and bleeding, or stabbing in the medulla were not very good, because of the long period before death in the former and manipulative difficulty in the latter. Immersing fish in ice-saline water containing 1% NaCl and 0.01% butyrated hydroxy anisole was better than immersion in ice-saline water containing 1% NaCl, or ice water, or icing with a mixture of 1% NaCl. Fish kept solely in crushed ice were the least desirable.

175 TSUCHIYA, Y., Y. SATO, Y. SUZUKI, H. KUDO, T. SASAKI, and M. MURASE. 1959. The influence of treatments immediately after catching on the quality of fish meat. II. Further examination of treatments on keeping quality of fish. Nippon Suisan Gakkaishi 25: 381–386.

Chlortetracycline was effective for preserving fish for long periods. Anesthesizing with urethane and then storing maintained good freshness for short periods.

176 TSUYUKI, H., U. NARUSE, AND A. SHIONOYA. 1961. Biochemical studies on the lipids of mackerel (*Scomber japonicus*). I. Characteristics of lipids in various parts of mackerel caught in the spring. Nippon Daigaku Nojuigakubu Gakujutsu Kenkyu Hokoku 13: 55–73.

The lipids obtained from the ordinary meat, red meat, viscera, head, skin, and nakaochi (a backbone with a small quantity of meat) of *S. japonicus* were separated into five fractions i.e., acetone-solution, lecithin, cephalin, sphingomyelin, and cerebroside; the characteristics were investigated. Cephalins obtained from the ordinary meat, head, and skin consisted mainly of phosphatidylserine, phosphatidylethanolamine, and an inositol-containing lipid.

177 VAN DE VELDE, A. J. J. 1932. Investigations on the chemical composition of fish. III. Composition of *Pleuronectes* and *Scomber*. Natuurwet. Tijdschr. 14: 178.

Gives results of analysis of water, lipids, protein, ash, phosphorus and chloride in the flesh, and percentage of offal of *Pleuronectes platessa* (flounder) and *Scomber scombrus* (mackerel) of different ages and sizes.

178 VIVIANI, R., P. CORTESI, L. MANCINI, AND A. R. BORGATTI. 1968. Lipolysis in the muscles of frozen mackerel (*Scomber scombrus*). Atti Soc. Ital. Sci. Vet. 22: 689–694.

Mackerel was stored at −20 C for 12 mo. Total and free fatty acid contents, before and after storage, were determined, together with the fatty acid composition of neutral fats and phospholipids and the individual free fatty acid content of mackerel muscle after storage. The results indicate that for frozen mackerel caught in April and having a low lipid level, free fatty acids represented 59% of the total fatty acids and appeared to be derived from both neutral fats and phospholipids. For frozen mackerel caught in September and having a high lipid level, the free fatty acids represented only 5% of the total fatty acids and appeared to be derived from neutral fats.

179 VOTH, M. D. 1949. Report on ether extract in fish. J. Assoc. Off. Agric. Chem. 32: 333.

The constants of crude fat (extracts) from canned mackerel were investigated further. The composition of this crude fat was found to be normal. The fish fats obtained by extracting with ethyl ether alone or with a mixture of ethyl ether and petroleum ether were identical for all practical purposes.

180 WARTENBERG, L., AND B. TREBUSIEWICZ. 1970. Nutritive value of herring paste. Med. Weter. 26: 491–493.

"Herring" paste is manufactured in the Wroclaw fish factory from the following recipe: minced fish fillets, 39.5%; margarine, 44.4%; paprika, 0.1%; tomato concentrate, 14.9%; and salt, 1.2%. The fillets may be from different hot-smoked fish including cod, buckling (fat

herring), mackerel, bluefish and Baltic herring. Tabulated compositional mean values with ranges for eight batches of paste include: moisture, 49.8 (46.8–51.7)%; protein, 15.1 (14.3–16.4)%; fat, 33.0 (30.8–36.6)%; salt, 2.22 (2.11–2.34)%; total P, 186 (148–304) mg/100 g; Ca, 29.4 (7.1–78.5) mg/100 g; and Fe, 0.23 (0.12–0.41) mg/100 g.

181 YANASE, M. 1956–57. The vitamin B_6 contents of fish meat. Nippon Suisan Gakkaishi 22: 51–55.

The vitamin B_6 content of fresh muscles of 23 species was determined with *Saccharomyces carlsbergensis*. *Scomber japonicus* contained 4.6–5.4 γ/g on wet basis. The vitamin B_6 content in the muscle of a given species of fish was slightly influenced by age, season, and location. Those fishes having larger proportions of red muscle and the more active ones contained larger amounts of vitamin B_6 in the ordinary muscles.

182 ZAMA, K. 1963. Phospholipids of aquatic animals. Hokkaido Daigaku Suisan Gakubu Kenkyu Iho 2: 73 p.

Data are given for amounts of total lipid, lipid-P, several phospholipids, and neutral fat in the ordinary and red muscle and liver of *Scomber japonicus*, as well as a number of other species.

183 ZIECIK, M., M. FIK, O. RZEWUSKI, AND A. FIK. 1971. Physico-chemical, microbiological and organoleptic investigations on sterilization process of mackerel colias product in its own liquor. Zesz. Nauk. Wyzsz. Szk. Roln. Szczecinie 35: (Rybactwo Morskie-2) 121–134.

Tests on mackerel *Scomber colias* canned in its own liquor were performed to determine optimum processing conditions for acceptable organoleptic properties while minimizing undesireable physicochemical and bacterial changes in the product. The optimum temperature and time range was found to be 112–120 C for 45–70 min. Organoleptic properties were acceptable in the product that was processed for the shortest time at the highest temperature. In addition, acceptable pigmentation was found to depend on the shorter processing period. To prevent unacceptable physico-chemical and bacterial changes, filled cans waiting sterilization should be held at room temperature no longer than $1\frac{1}{2}$ h.

184 ZITKO, V. 1971. Polychlorinated biphenyls and organochlorine pesticides in some freshwater and marine fishes. Bull. Environ. Contam. Toxicol. 6: 464–470.

Concentrations were measured in mackerel and nine other species. Distribution of PCB, *p,p'*–DDE, *p,p'*–DDD, *p,p'*–DDT, and C_6Cl_6 is tabulated. Of the organochlorine pesticides, *p,p'*–DDE was present in highest concentration, followed by *p,p'*–DDT and *p,p'*–DDD. Most samples contained a small amount of hexachlorobenzene. PCB are less toxic to fish than organochlorine pesticides, but no conclusions can be reached at the present time about the sublethal effects of PCB and their toxicological significance in fish.

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