Studies on the storage of iced mackerel (*Scomber japonicus*). 1. Quality changes during storage

LYDIA A. BONSU (Mrs) & PENELOPE J. SUTCLIFFE (Miss)
(L.A.B.: Food Research Institute, P.O. Box M-20, Accra, Ghana; P.J.S.: Tropical Products Institute, 56-62 Gray's Inn Road, London WC1 X 8LU, England)

SUMMARY

Samples of mackerel (*Scomber japonicus*), caught off the coast of Ghana, were iced alive and stored for 23 days. The quality during storage was assessed by sensory and objective methods. The spoilage of mackerel as determined by visual and olfactory assessment occurred in four phases. In phase one, incipient deterioration in quality occurred and all the fish were in *rigor mortis*. The fish passed out of *rigor* in phase two, and the iris changed from yellow to black. As the fish entered phase three, the flesh began to soften, the skin started fading and wrinkling and a yellow slime appeared. In phase four, putrid odours were detected. The fish remained acceptable up to 19 days in ice. Various objective tests of quality were studied but only the overall freshness as measured by the Rank-Torry freshness meter and hypoxanthine showed potential for use as indices of quality. The *p*H value showed potential as a spoilage indicator.

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RÉSUMÉ

BONSU, LYDIA A. (Mme) & SUTCLIFFE, PENELOPE J. (Melle): *Etudes sur la conservation du maquereau* (Scomber japonicus) *congelé. 1. Changements de qualité pendant la conservation.* Des lots de maquereaux (*Scomber japonicus*), capturés au large des côtes du Ghana, ont été congelés vivants et conservés 23 jours. La qualité, pendant la conservation, a été estimée par des observations sensorielles objectives. La détérioration des maquereaux, appréciée par des évaluations visuelles et olfactives, s'est produite en 4 phases successives. Pendant la première phase, un début de déterioration de la qualité apparut tandis que le poisson était au stade de la rigidité cadavérique. La rigidité disparut pendant la phase deux et l'iris de l'oeil vira du jaune au noir. Comme le poisson entrait dans la phase trois, la chair commenca à se ramollir, la peau à se flétrir et se rider tandis qu'apparaissait une mucosité jaune. Dans la phase quatre, une odeur putride était perceptible. Le poisson est demeuré acceptable dans la glace pendant 19 jours. Différents tests objectifs de qualité ont été essayés, mais seule la fraîcheur totale mesurée soit au moyen de l'appareil G.R. Torry électronique (Voir Jason et Richards, 1975), soit par l'estimation enzymatique de l'hypoxanthine (Jones, Murray & Burt, 1965 - Cameron, 1969) ont fait montre de possibilités d'utilisation pour déterminer la qualité. L'évaluation du Ph peut jouer le rôle d'indicateur de détérioration.

Introduction

Fish becomes inedible after 24 h at ambient temperatures in the tropics. Therefore, the distribution of fresh fish is generally restricted to coastal areas where the fish is processed before distribution inland. Investigations in the tropics have indicated that ice can be used to extend the shelf life of fresh fish and thus, encourage wide distribution.

In East Africa, Disney *et al.* (1969) and Hoffman *et al.* (1973) have reported an extension in the shelf life of several East African freshwater species to approximately 4 weeks by chilling in ice immediately after the fish have been harvested. Similar studies on Indian freshwater and marine species have shown that the fish could remain acceptable for up

to 5 weeks (Velankar & Kamasastri, 1956; Govindan, 1971; Balakrishnan Nair, Tharamani & Lahiry, 1971). An investigation into the value of volatile nitrogen methods for quality assessment in West African marine fish showed that the species remained acceptable for 17-20 days in ice whereas all were completely spoiled within 24 h at ambient temperature (Aldrin, Ambroggi & Pony Assemien, 1970). Amu & Disney (1973) have also confirmed the view that chilling in ice can extend the storage life of fresh tropical fish. They reported that four West African marine species could remain edible for 3 weeks when iced immediately after capture.

In Ghana, ice is used commercially to preserve fish at sea but this is limited to a few inshore vessels which operate from Tema Fishing Harbour where there are ice-making plants. The limited use of ice has been caused by lack of information on the benefits of icing fish and the lack of ice making plants at many landing sites. Most of the inshore vessels are compelled to land the catch soon after harvesting but because of the high ambient temperature the quality of the fish is generally poor.

The objectives of the present study were to extend the range of observations on West African species and to study the changes in quality which occurred during iced storage of mackerel (*Scomber japonicus*). This study will provide information which can be used to encourage icing of fish at sea and during distribution. It will also serve as a basis for the introduction of fish inspection and quality control which will become necessary as the demand for good quality fresh fish increases.

Materials and methods

The fish were caught off Tema shore by purse seine at a depth of 55 m. Samples containing 70 fish of similar size (average weight of 130 g) were iced immediately the fish were hauled on to the deck. The icing procedure consisted of arranging the fish with alternate layers of flaked ice in an insulated box. The box was constructed from plywood and insulated with polystyrene (7.5 cm in thickness). Ice was replenished when necessary and samples of fish were removed at regular intervals for sensory and objective assessment of quality.

Sensory methods

Visual and olfactory assessment. Nine fish were examined for signs of spoilage. Particular attention was paid to the condition of the eyes, colour and odour of the gills, firmness of the flesh and belly, the amount and odour of the body slime and the colour of the skin.

Taste panel assessment. Five of the nine fish were cleaned, cut into chunks and cooked in 1 per cent (w/v) brine for 30 min. The eating quality of the fish in terms of taste, odour and texture was assessed by a panel of eight. An eleven-point hedonic scale from 0 (lowest) to 10 (highest quality) was used to assess the overall acceptability.

Objective methods

The remaining four fish were used for the following determinations.

Over-all freshness. The freshness of the fish was measured with the Rank-Torry freshness meter which has arbitrary calibrations from 0 to 100. Duplicate readings were taken near the lateral line, midway along the fish. The Rank-Torry meter is no longer available but it has been replaced by the GR-Torry meter (Jason & Richards, 1975) which is an improvement on the Rank-Torry meter.

Total viable bacterial count. The anterior dorsal region of one side of the fish was swabbed with alcohol and an area of the skin was removed with sterile instruments. Five grams of the underlying muscle were removed aseptically and homogenized in 45 cm^3 of ¼ strength Ringer's solution. Serial dilutions were prepared and put on plates of Oxoid plate count agar using the pour plate method. The plates were incubated at 30 °C for 3 days and counts in the range of 30 - 300 were taken.

Total volatile bases (TVB). About 2 g of muscle from the anterior dorsal portion of the fish were homogenized in 14 cm^3 of 6 per cent (v/v) perchloric acid solution at 0 °C. The homogenates were filtered and aliquots of 1 cm^3 were used to determine the total volatile bases by a procedure based on the micro-diffusion method of Conway (Beatty & Gibbons, 1937).

Hypoxanthine concentration. A neutralized perchloric acid extract prepared from 1g of muscle was used for the enzymatic estimation of hypoxanthine (Jones, Murray & Burt, 1965; Cameron, 1969).

Thiobarbituric acid value (TBA). Duplicate samples of about 1g muscle were refluxed with 3 cm^3 water and 10 cm^3 20 per cent trichloro-acetic acid for exactly 30 min. Then 75 cm^3 pyridine hydrochloride thiobarbituric acid reagent were added without shaking and the refluxing continued for 10 min. After cooling to room temperature, 40 cm^3 of the refluxed solution were centrifuged at 1800 rpm for 5 min. Then 15 cm^3 of the supernatant solution was shaken vigorously with 10 cm^3 petroleum ether for 30 s and centrifuged at 1200 rpm. When cloudiness occurred, the solution was shaken again with petroleum ether and centrifuged. The supernatant ether layer was discarded and the optical density was measured at 535 nm against a blank solution using Optica Spectrophotometer (Yu & Sinnhuber, 1957).

Hydrogen ion concentration (pH). Duplicate samples of 2.5 g muscle were homogenized in 40 cm^3 0.005*M* sodium iodoacetate solution. This volume was required to cover completely the probes of the *p*H meter used. The *p*H of the homogenate was measured with an EEL *p*H meter (Benson, 1928).

Results and discussion

Results of olfactory and visual assessment are recorded in Table 1. The changes in the quality of mackerel can be divided into four phases. In phase one, which occurred between harvesting and 6 days of iced storage, deteriorative changes were just evident. Most of the fish were in *rigor mortis* and their eyes were slightly sunken and opaque. During phase two, all the fish passed out of *rigor mortis*; the skin became dull and pale, the eyes were sunken and contracted with the iris changing from yellow to black. These changes occurred during 6 - 12 days of iced storage. In phase three, the skin started losing the characteristic mackerel markings and colour. Wrinkles appeared and a yellow slime was formed. The belly became progressively soft and broken in some fish. This phase covered 12 - 19 days of storage. The fourth phase occurred after 19 days when putrid odours were detected and all the characteristic markings on the skin were lost.

Fig. 1 shows taste panel scores, overall freshness and hypoxanthine levels during storage of iced mackerel. The eating quality of the fish, determined by taste panel, remained the same during the first 8 days of storage. However, there was a steady loss of quality beyond 8 days. A score of 5 on the 11-point scale used indicated the limit of acceptability. On this basis, the storage life of iced mackerel was 19 days. At this point the taste panel described the flavour of the fish as nauseous and "off".

The overall freshness which is determined by the Rank-Torry freshness meter is a measure of the changes in the dielectric properties of fish tissue during iced storage. The meter was designed originally for iced cod (temperate fish) but it showed potential as a measure of quality of tropical fish during iced storage (Amu & Disney, 1973). Results of the present study show a rapid loss of freshness during the initial 6 days of storage. The loss of "freshness" was slow after 6 days suggesting that the meter cannot be used to measure the quality of mackerel after phase one of spoilage. However, the meter is capable of measuring incipient deterioration in quality during phase one.

The hypoxanthine levels during storage are shown in Fig. 1. Hypoxanthine is a product of autolysis. After death, the adenosine triphosphate (ATP) of fish muscle breaks down and one of the resulting substances is inosine monophosphate (IMP) which is known to contribute to the pleasant flavours of fresh fish. During storage IMP is degraded to hypoxanthine which contributes to the development of bitter "off" flavour of stale fish (Jones *et al.*, 1964). The rates of degradation of IMP vary from one species to the other. Results of the present study show that hypoxanthine levels were very low up to 8 days of storage when the eating quality of the fish was good. Hypoxanthine levels increased steadily up to 19 days and fell slightly thereafter. (Taste panel scores also decreased

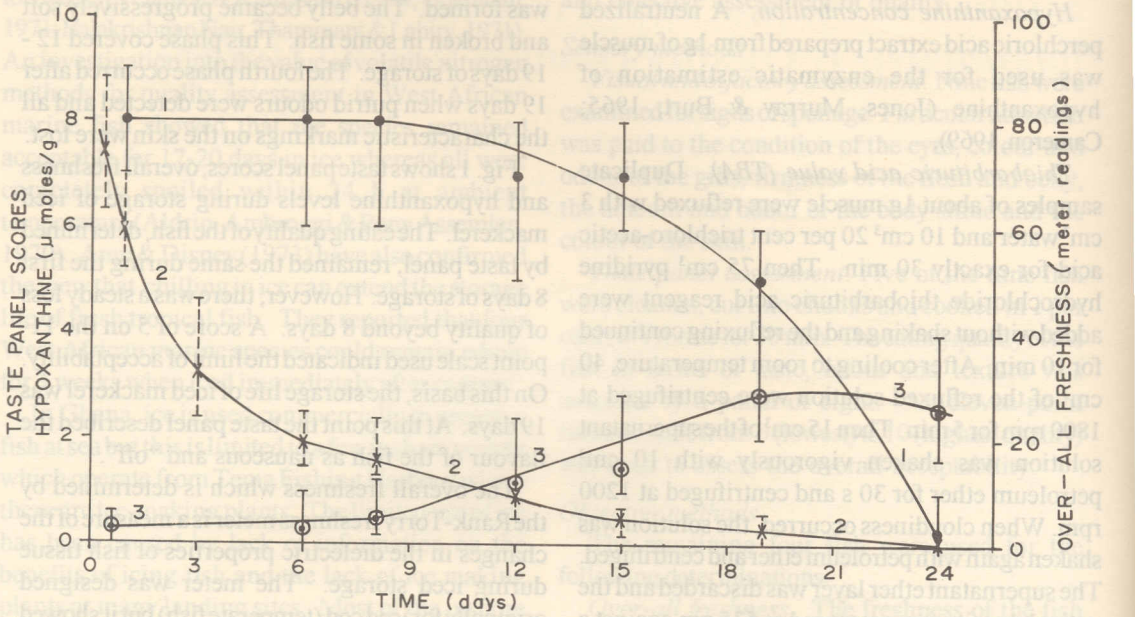

Fig. 1. Taste panel scores (1), overall freshness meter readings (2) and hypoxanthine levels (3) during iced storage of mackerel.

rapidly during this period). At the limit of acceptability when the taste panel score was 5, the concentration of hypoxanthine was 2.5 moles per gram. This level then indicates the limit of acceptability of mackerel when hypoxanthine alone is used to measure quality.

Other objective methods which did not show potential as indices of quality were the total volatile bases (TVB), thiobarbituric acid value (TBA), *p*H and total viable bacterial counts. These are shown in Table 2.

Total volatile bases (TVB) are produced as a result of bacterial degradation of trimethylamine oxide (TMAO) found in the flesh of fish. The concentration of TVB is, therefore, related to the degree of bacterial spoilage and a value of 30 mg nitrogen per 100 g muscle is used as the limit of edibility for most temperate fish (Tillmans & Otto, 1924). The TVB values shown in Table 2 were comparatively low even when the fish was considered to be unsuitable for consumption. The values showed no linearity with the days of storage. It has been reported by Simidu (1961) that TMAO, the precursor of TVB, occurred in low levels in the flesh of pelagic fish. Therefore, the present low TVB values might be due to the low TMAO in the fish. Wierzhochowski (1956) reported that the TVB value was of no value in determining the freshness of herring. Similar observations of low and non linear values of TVB have been reported by Amu & Disney (1973) for some species of West African pelagic fish.

The total viable bacterial counts in the flesh of the fish are shown in Table 2. There was a lag phase up to 8 days; thereafter, the bacterial numbers increased steadily to about 10^6 per gram of muscle after 23 days of storage when the fish was rotten. The bacterial numbers were low in comparison with values reported for temperate fish. Shewan (1961) observed that bacterial numbers in iced temperate fish, such as cod, increased after a lag phase of 1 - 2 days to about 10^7 - 10^8 per gram muscle after 9 - 10 days. The low bacterial numbers reported in Table 2 was partly due to the retardation of growth caused by the intolerance of tropical bacteria to ice temperatures and partly due to the washing effect

TABLE 1

*Visual and Olfactory Assessment of Mackerel (*Scomber japonicus*) during Iced Storage*

Days of iced storage	*Condition of*			
	Eyes	*Gills*	*Flesh*	*Skin*
Before icing	Translucent, black pupil, yellow iris	Bright red, seaweed odour, no slime	Very firm fish alive	Glossy, characteristic markings and colour present, no slime
1	As above	Dark red, seaweed odour, transparent slime	Very firm in *rigor mortis*	As above
6	Slightly sunken and opaque pupil, yellow iris	Brownish-red, neutral odour, transparent slime	Firm, most fish in *rigor mortis*	As above, but neutral body odour
8	As above, but pupil contracting	Brownish-red, neutral odour, opaque slime	Firm, all fish out of *rigor mortis*	Less glossy, becoming pale, neutral body odour
12	Sunken, contracted, and very opaque pupil, iris turning black	Leached, brownish-red, slightly stale odour, opaque slime	Fairly firm, with soft belly	Dull skin, pale in colour, no slime, neutral odour
15	Very sunken and contracted, very opaque pupil, black iris	Leached, brownish-red, opaque slime	Fairly firm, soft belly beginning to break	Slightly wrinkled, dull and losing characteristic markings, slimy, stale odour
19	As above but bloody	Leached, dark maroon, fairly heavy slime, nauseous odour	Soft belly broken in some fish	As above but bleached in colour, wrinkled and thick yellow slime
23	As above	As above but slime and odour have increased in intensity	Very soft, belly of all fish broken	Wrinkled, bleached in colour, loss of characteristic markings, thick yellow slime with putrid odour

of melted ice. Similar low bacterial numbers have been reported for other species of tropical marine fish (Velankar & Kamasastri, 1956; Govindan, 1971; Amu & Disney, 1973). The low bacterial numbers partly accounted for the low TVB values recorded during storage.

The thiobarbituric acid value (TBA) is a measure of rancidity in fatty foods. As fish oil goes rancid, malonaldehyde is produced and it reacts with 2-thiobarbituric acid to yield a pink or red compound, the intensity of which is a measure of the degree of autoxidation of the lipids. The TBA values recorded in Table 2 were low suggesting that there was little autoxidation of the lipids although rancidity was expected to occur because of the high fat content of the fish. (The mean fat content was 11 per cent with a range of 7 to 21 per cent for 10 fish). A possible reason for the low TBA values might be

TABLE 2

Total Volatile Bases (TVB) Thiobarbituric Acid Value (TBA) pH *and Total Viable Bacterial Counts of Mackerel (*Scomber japonicus*) during Iced Storage*

Days of iced storage	*TVB (mg percent N)*		*TBA (optical density per g)*		pH		*Total viable bacteria (counts per g muscle)*	
	Mean	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*
1	2.9	2.4 - 3.2	0.02	0.01 - 0.03	6.3	6.1 - 6.4	$< 3.0 \times 10^2$	-
6	4.7	4.2 - 5.0	0.03	0.02 - 0.05	6.0	5.8 - 6.2	$< 3.0 \times 10^2$	-
8	2.6	2.0 - 3.4	0.11	0.10 - 0.14	6.2	6.0 - 6.4	$< 3.0 \times 10^2$	-
12	3.8	3.5 - 4.3	0.09	0.06 - 0.12	6.0	5.9 - 6.2	7.7×10^3	4.0×10^2 - 3.0×10^4
15	2.2	1.6 - 2.6	0.09	0.08 - 0.13	6.2	6.1 - 6.3	1.8×10^4	2.0×10^3 - 3.5×10^4
19	4.4	4.5 - 6.3	0.14	0.09 - 0.16	6.8	6.6 - 7.1	1.8×10^5	5.0×10^4 - 3.2×10^5
23	6.3	6.0 - 6.5	0.11	0.09 - 0.14	7.7	7.5 - 7.9	8.1×10^5	3.0×10^4 - 2.0×10^6

that the oxidized lipids became hydrolysed and were leached out during storage. This reason is supported by the taste panel results in which no rancid flavours were recorded even at the limit of acceptability.

The *p*H of the muscle is shown in Table 2. The *p*H was weakly acidic and remained fairly constant up to 15 days. Thereafter, there was a rise towards neutrality and during the same period, a thick yellow slime was observed on the fish and the gills developed nauseous odours. A rise in *p*H value is, therefore, indicative of spoilage.

Conclusion

The experimental results indicated that mackerel (*Scomber japonicus*) remained acceptable up to 19 days when iced immediately after capture. This period is long enough to permit extensive exploration of grounds during fishing. It will also permit wide distribution of fresh fish over inland areas assuming that other factors such as good roads and suitable transport facilities are present.

As the demand for good quality fresh fish increases, it will become necessary to introduce fish inspection and quality control. In the initial stages, sensory methods such as those studied will be used, but in the longer term objective quality control indices are required. In the present study the objective methods which showed potential for use as indices of quality were the overall freshness value which was useful up to 6 days of storage and hypoxanthine concentration after this period up to the limit of acceptability. The *p*H of the flesh could be used as an indicator of spoilage.

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