MAXIMISING ECONOMIC RETURNS IN THE NORTHERN TERRITORY SPANISH MACKEREL FISHERY

Project 92/124.24

SubProject: Phase 2: Shelf-life study of fresh chilled Spanish mackerel.

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SUMMARY

The shelf-life of Spanish mackerel caught by line fishing in Northern Australian waters was evaluated. Spiked fish were stored in ice either headed and gutted or left uncut and subjected to sensory, nucleotide, pH, histamine and microbial analysis and the rigor pattern recorded. There was little difference between the two product forms. Rigor in uncut fish lasted for 14±9.8 hours and in headed and gutted fish for 19.6±16.3 hours. Spanish mackerel retained good sensory quality for up to 14 days. The bacterial load reached 105 cfu/g by 18 days. K values were low for most of the storage time (<40%). Histamine levels did not develop more than 10mg/kg during storage. The pH of Spanish mackerel did not drop below 6.0 even when bacterial levels become high.

BACKGROUND

The Northern Territory fishery for Spanish mackerel grew from small catches in the mid 1970s to an annual catch of 270 tonnes in 1990. Catches then declined to 132 tonnes in 1993, possibly reflecting management restrictions which were introduced in 1990. The value of production in 1990 was estimated at $700 000.

Spanish mackerel is caught by trolling from small dories or large boats. A single lure or bait is towed through the water on a trolling line, with all fish caught and handled individually. Currently the fish are processed by bleeding and killing, before fillets are removed for packaging and freezing in fillet blocks. The majority of the catch in established fisheries is sold as frozen fillet blocks.

The Spanish mackerel is unusual as the fish are handled as a bulk commodity although they are captured and killed individually. Bulk packs are typically the product of more mechanised capture techniques such as gill netting and trawling whereas individually captured fish are normally sold as high value fresh/chilled products.

Unfortunately trial shipments of chilled Spanish mackerel to east Asian markets have not been successful because of problems with quality. This highlights the need for information on the markets and on the specific handling practices required to enhance product quality and shelf-life.

NEED

Preliminary indications suggest there is a significant market for Spanish mackerel in east Asian markets. Unfortunately trial shipments have been less than satisfactory because of problems with product quality. This highlights the lack of objective data on these markets and the specific fish handling practices necessary to guarantee the quality of fish.

This subproject seeks to identify fish handling and storage practices which are necessary to ensure fish meet market requirements for freshness and quality. The information gathered during these studies will then be incorporated into a Code of Practice and training programs.

OBJECTIVES

1. To assess the impact of bleeding, gutting and deheading on the quality of Spanish mackerel.

2. To determine the impact of spiking and icing on the onset of rigor in Spanish mackerel.

3. To evaluate the effect of storage on ice on the shelf-life and sensory properties of Spanish mackerel.

4. To assist in the preparation of a Code of Practice for capture, handling and packaging of chilled Spanish mackerel.

INTRODUCTION

The Spanish mackerel fishing industry in the Northern Territory are looking to expand markets both domestically and in East Asia. The fish are caught by gill netting or trolling and are mainly produced as bulk packed frozen fillets. Trial shipments of chilled mackerel to the latter markets have been found to be of unsatisfactory quality. Most fish sold on the domestic market are presented headed and gutted. A study of the market for mackerel in Hong Kong and Taiwan, undertaken by the author (Slattery, 1995), identified a preference for uncut fish. Fish with head and gut removed were devalued, as these components are utilised by the Asian consumer.

The storage life for acceptable sensory quality of seafood chilled in ice can vary from 5 to 8 days for small fatty fish, to 30 days for some species from tropical waters (Sikorski and Sun Pan, 1994). This study was carried out to investigate handling practices on board the capture vessels and a variety of parameters were used to determine the shelf-life of two product forms. Progression of rigor, pH, nucleotide breakdown profile (K value), histamine, bacterial load and organoleptic rating using a demerit point assessment score were appraised. The Scombridae family (tuna, mackerel, bonito) are prone to the production of histamine (Middlebrooks et al., 1988) so this aspect was included to help determine quality.

MATERIALS AND METHODS

Two field trips were undertaken to obtain Spanish mackerel from Northern Territory waters near Darwin. A vessel and fishers were supplied by industry and they were assisted by officers from the Northern Territory Department of Primary Industry and Fisheries and Queensland Department of Primary Industries.

Two types of product forms were evaluated. The fish were landed quickly after being hooked on troll gear and spiked in the brain (commonly refered to as iki jimi).

Rates of progression through rigor, breakdown of nucleotides and increase in lactic acid level were slower in fish which had been spiked when compared to fish which had been temperature shocked or left to struggle (Oka et al., 1990 and Mochizuki and Sato, 1994). These parameters impact on the shelflife and overall quality of the product presented for sale.

After spiking the fish were placed in an ice slurry either uncut or after the removal of the head and gut. They were then airfreighted to Brisbane where they were stored under ice. A total of 8 uncut and 9 headed and gutted Spanish mackerel ranging from 5 to 20kg in size were subsampled regularly over a 25 day storage period.

Rigor Condition

The rigor condition of Spanish mackerel was measured using the method of Iwamoto and Yamanaka (1986), which measures the vertical displacement at the fork of the tail when half of the body of the fish is unsupported. It is expressed as a percentage of the prerigor measurement. The rigor index is 100% when a fish is fully in rigor and when rigor starts to extinguish the index falls below this measurement.

pH

The pH of the muscle tissue at the head region was recorded using a stab electrode attached to a hand held digital pH-mV Meter LC80A (TPS Electronics Pty Ltd, Brisbane, Australia)

Nucleotide Assay and K value

The K value is a measure of nucleotide breakdown in the flesh (Huynh et al., 1992). Mackerel muscle tissue was processed for nucleotides and the K value assessed using the method of Williams et al. (1993).

Histamine

A limited number (6) of randomly selected samples taken at two different storage times were analysed for histamine content using the AOAC official method 977.13 (AOAC, 1980).

Microbial Analysis

The test sample was prepared by aseptically subsampling 10 g from each mackerel and transferring it into a sterile stomacher bag. The subsample was diluted 1:10 with 0.1% peptone diluent. The mixture was then disrupted in the stomacher for 60 seconds. The total bacterial counts, reported as the number colony forming units per gram (cfu/g), were determined by the surface spread method (Australian Standard, 1991) using nutrient agar. The plates were incubated at 25°C for 3 to 4 days.

Total count for hydrogen disulphide (H_2S) producing organisms was performed with the pour plate method using iron agar (Gram et al., 1987), when set, the agar was overlayed with the same agar. The plates were incubated aerobically at 25°C for 3 days.

Organoleptic Rating

A wide variety of parameters were appraised by four trained panellists. Score sheets, developed at the Centre for Food Technology and based on the method of Stone et al. (1974) were used to assess the quality of uncut and headed and gutted fish. The parameters and anchor points used were skin appearance (very bright-dull), loss of skin/scales (none-excessive), skin and flesh texture (firm-soft), slime (absent-very slimy), stiffness (prerigor-postrigor), flesh cross section (translucent-dull), odour (no off odours-off odour), flavour (very sweet-spoilt) and texture (chewy-soft). These scores were combined to produce a total score for each product form. A number of other parameters were evaluated but these were not common to both product forms. The score sheets are present in Appendix 1 as Figures 1 and 2.

Statistical Analysis

At a particular storage time the two product forms were compared using one way analysis of variance. Insufficient fish were available for testing at each storage time so the same fish were subsampled and evaluated. The treatment mean and variance are displayed in each table along with significance testing at the 5% level. The total microbial count was $\log_{10}$ transformed, while the proportion of the total count that were H_2S producers transformed to a square root and then arcsine prior to analysis.

RESULTS AND DISCUSSION

The impact of spiking and icing on the onset of rigor in Spanish mackerel set out in Objective 2 were not assessed due to insufficient fish numbers. The results section which follows has been prepared as a paper which has been submitted to the Journal of Aquatic Food Product Technology.

Rigor condition

The progression into rigor by mackerel, after spiking, was rapid. The graph in Figure 3 in Appendix 1 shows that uncut fish were in rigor 14 ± 9.8 hours (mean$\pm$standard error). Most of the fish were firm with a rigor index of over 50% for up to 30 hours after capture, before softening. Rigor had extinguished for the majority of fish (rigor index <50%) by 60 hours but it took much longer for the muscles to be relaxed enough for all the fish to be close to the prerigor measurement. This is a common occurrence in fish treated by spiking (Boyd et al., 1984). Some of the fish never returned to the original measurement. Bito et al. (1983) classified this as a Type 2 rigor pattern and it is common to several mackerel species.

The differences in progression of rigor exhibited by the mackerel can be due to a number of parameters such as the reserve of ATP due to time of last feeding and amount of struggling upon capture (Stroud, 1969 and Wells, 1987) and temperature (Iwamoto et al., 1987). Iwamoto et al., (1987) found that spiked plaice took three hours to go into rigor when stored at 0°C but longer when kept at higher temperatures. The plaice then stayed in rigor for 72 hours. Cultured red sea bream take 6 hours to fully enter rigor (Iwamoto and Yamanaka, 1986).

Figure 3 also shows the headed and gutted mackerel stayed in rigor longer than the whole fish and were much slower to soften. Rigor in these fish lasted for 19.6 ± 16.3 hours. One fish was very firm for 86 hours (rigor index >85%). This is not surprising as it was the only fish with a significant amount of ATP (0.43µmoles/g) upon delivery to Brisbane. None of these fish returned to the prerigor measurement. This treatment provides a similar extension of rigor time as that seen when coring of the spinal cord is carried out (Ando et al., 1996). Scott et al. (1986) found the shelf life of orange roughy was extended only slightly with heading and gutting.

pH

The final pH of most fish during chilled storage is around 6.2-6.6 and low pH has been associated with textural deterioration (Izquierdo-Pulido et al., 1992). There was not much variability between the pH of individual mackerel. Table 1 shows the mean pH for each treatment, the variance and whether they were significantly different during storage. The pH of Spanish mackerel was quite stable during storage. There were three sampling times when the headed and gutted fish had significantly lower pH, but in real terms this was not more than 0.24 of a pH unit. This stability is reflected in the retention of quality observed during storage.

Common mackerel (*Scomber japonicus*) display an increase in pH during storage from below 6 to above 7 after 12 days storage at 5°C (Sato et al., 1994). They found that as the sample putrefied, the pH became neutral and the histamine content decreased due to histamine-decomposing bacteria. These authors also state that the optimum pH for histamine forming bacteria is 5.0-6.0, while the highest activity of histamine decomposing bacteria is detected at pH 7.0-7.5. The ultimate pH in fish flesh also has a large impact on the texture (Sikorski and Sun Pan, 1994).

Table 1. Changes in pH during storage of headed and gutted and uncut Spanish mackerel in ice.

Treatment	Time (d)						
	0	2	7	14	18	22	25
gutted pH	6.45	6.50	6.54	6.50	6.09	6.31	6.24
uncut pH	6.52	6.63	6.52	6.44	6.33	6.30	6.44
variance	0.020	0.073*	0.002	0.018	0.233*	0.001	0.165*

* Indicates there is a significant difference between the two means (P<0.05)

K value

The mean K values for both treatments can be seen in Table 2. There was little difference between the two product types of mackerel for K value, except at the start of storage. Spanish mackerel in this study exhibited lower K values than Alaska pollack, Pacific cod and Japanese black and red bream during ice storage (Ehira and Uchiyama, 1974).

Table 2. Changes in K value during storage of headed and gutted, and uncut Spanish mackerel in ice.

Treatment	Time (d)					
	2	7	14	18	22	25
gutted K value	5.7	7.8	23.1	25.8	31.3	36.0
uncut K value	3.7	7.5	21.3	30.4	33.7	33.1
variance	16.30*	0.33	13.13	84.8	23.70	36.80

* Indicates there is a significant difference between the two means ($P<0.05$)

The levels of nucleotide compounds that contribute to the K value with bitter taste, such as hypoxanthine (not presented here), did not increase markedly until day 14. The level of hypoxanthine in Pacific mackerel (*Scomber australasicus*) when stored under chilled sprays (-0.5 to -1.5°C) of salt water (Boyd and Wilson, 1978) was much higher by this time than Spanish mackerel stored in ice. The K value by this time was also low (<25%). Studies of Faughn's mackerel (*Rastrelliger faughni* Matsui) by Barile et al. (1985) found the K values of well iced fish to be over 60% after 14 days storage while spiked yellowtails (Seriola quinqueradiata) stored at 0°C had a lower K value than Spanish mackerel after 48 hours (Oka et al., 1990).

The data obtained suggests that the rate of enzymic activity which breaks down nucleotides is slow in Spanish mackerel. Bremner et al. (1988) found that the shelf life of tropical species of fish from the North West Shelf of Australia was related to the breakdown rate of inosine monophosphate (IMP), one of the nucleotide metabolites, rather than to bacterial spoilage. This could also be the case with Spanish mackerel as the IMP levels were still moderate (>3.3μmoles/g) at day 25. The K values of the former species ranged from 30 to 60% after 14 days storage while this study found Spanish mackerel to be much lower.

Histamine

A total of six samples were analysed for histamine content. These were taken randomly at two different storage times. At day 7 the histamine content of Spanish mackerel was less than 10mg/kg. By day 18 two levels had increased slightly so that two of the three fish had histamine concentrations of 10mg/kg. Histamine production is a function of microbial enzymatic activity. Histamine is formed by the decarboxylation of the amino acid histidine by the microbial enzyme histidine decarboxylase and thus is dependent on the temperatures a product is kept at prior to consumption. Taylor (1988) states that histamine represents a problem only when levels approach or exceed 500mg/kg in fish and other foods. The low levels detected in this study of Spanish mackerel indicate that when good handling practices are applied histamine poisoning should not occur.

Microbial Analysis

The mean log counts for the two types of mackerel, during storage in ice, can be seen in Table 3. The fish did not develop counts above 10^4 cfu/g (a level when defects due to microbial activity become apparent) until day 14. The bacterial count for headed and gutted fish progressed in a similar way to the uncut fish up to day 18. There was a significant difference between the treatments at day 22 when the uncut fish had lower log counts. The gutted and headed fish developed high counts ($>10^6$ cfu/g) by day 22 while the count in uncut fish did not reach this level until day 25. Scott et al. (1986) found no differences between headed and gutted and whole orange roughy during storage in ice. They had bacterial counts in the flesh of between 10^5 and 10^6 cfu/g after 16 days and were considered spoiled. Spanish mackerel from both treatments developed these counts by day 18.

Table 3. Changes in the microbial log count of Spanish mackerel in ice.

Treatment	Time (d)					
	2	7	14	18	22	25
gutted (log cfu/g)	0.70	1.68	4.65	5.61	6.42	6.32
uncut (log cfu/g)	1.15	2.02	4.38	5.39	5.54	6.27
variance	0.859	0.493	0.311	0.201	3.261*	0.012

* Indicates there is a significant difference between the two means ($P<0.05$)

The log count and the analysis of the transformed proportion that the log count of H_2S producing colonies contributed to the total bacterial count is present in Table 4. The counts of H_2S producing bacteria which developed in chilled Spanish mackerel during storage were low. When they were present the proportion of this count to the total bacterial count ranged from 1-18%. Such low counts for H_2S producers are consistant with the low scores for off odours. There were no significant differences between the two treatments for H_2S producers. The production of H_2S is one of the prominent characteristics of fish spoilage bacteria (Gram et al., 1987). Similar results have been reported for orange roughy (Scott et al., 1986).

Table 4. Changes in the hydrogen disulphide producing microbial load of Spanish mackerel in ice.

H_2S producing colonies	Treatment	Time (d)			
		2	18	22	25
	gutted cfu/g	0	2.29	3.40	3.87
log count	uncut cfu/g	0	0.85	2.16	2.80

	variance	0	8.788	6.516	4.853
arcsine square root of (H_2S count/total count)	gutted	0	0.046	0.095	0.103
	uncut	0	0.079	0.305	0.235
	variance	0	0.1465	1.4147	0.7237

* Indicates there is a significant difference between the two means (P<0.05)

The bacterial load of Pacific mackerel (*Scomber australasicus*) stored under chilled (-0.5 to -1.5°C) sprays of salt water (Boyd and Wilson, 1978) was much higher than those identified in Spanish mackerel at similar storage times. Much higher counts were also obtained from another fish called "Spanish mackerel" (*Scomberomorus maculatus*) held under similar conditions (Middlebrooks et al., 1988). The total count in minced common mackerel increased quickly to 10^{10} cfu/g after 12 days at 5°C (Sato et al., 1994).

Tropical fish are generally less prone to rapid spoilage and exhibit longer refrigerated shelf life than cold water species (Ward, 1994). The growth rates of bacteria in Spanish mackerel in this study was slow when compared to many other species and the change in log count was linear. The bacterial load of Spanish mackerel was lower by at least one log count than reported for orange roughy (Scott et al., 1986), a species renown for its stability and good shelf life.

Organoleptic Rating

Table 5 following lists the means and the variance for each treatment and the total score for those demerit parameters that were shared by both treatments, at each storage time.

Table 5. Changes in sensory attributes evaluated in Spanish mackerel during storage in ice.

Sensory Attribute	Treatment	Time (d)					
		2	7	14	18	22	25
Skin appearance	gutted	0.14	0.76	1.31	1.97	2.14	2.71
	uncut	0.23	1.00	1.53	1.88	2.25	2.27
	variance	0.035	0.236	0.216	0.040	0.052	0.830*
Loss of skin/scales	gutted	0.14	0.67	1.07	1.29	1.44	1.83
	uncut	0.08	0.92	1.11	0.91	1.42	1.45
	variance	0.016	0.276	0.007	0.629*	0.002	0.612*
Skin & flesh texture	gutted	0.04	0.44	0.49	0.69	0.85	0.97
	uncut	0.09	0.56	0.56	0.66	0.81	0.69
	variance	0.012	0.059	0.025	0.006	0.005	0.343*
Slime	gutted	0.07	0.46	1.03	1.32	1.93	2.44
	uncut	0.02	0.55	1.17	1.44	1.83	2.09

	variance	0.012	0.033	0.088	0.059	0.044	0.521*
Stiffness	gutted	0.81	1.83	1.83	2.00	1.94	2.00
	uncut	1.25	1.84	2.00	2.00	2.00	1.97
	variance	0.837*	0.001	0.118	0	0.013	0.004
Flesh (cross section)	gutted	0.08	0.40	0.72	0.83	0.99	1
	uncut	0.06	0.41	0.72	0.81	1	0.92
	variance	0.002	0.004	0	0.002	0.001	0.026
Taste (odour)	gutted	0	0.28	0.89	0.99	1.17	1.28
	uncut	0	0.28	1.05	0.88	1.17	1.11
	variance	0	0	0.106	0.52	0	0.118
Taste (flavour)	gutted	0.71	1.18	1.60	1.86	2.29	2.44
	uncut	0.81	1.08	1.83	1.84	2.19	2.22
	variance	0.046	0.44	0.230	0.001	0.046	0.216*
Taste (texture)	gutted	0.28	0.38	0.83	0.86	1.04	1.07
	uncut	0.30	0.52	0.97	0.75	1.09	1.05
	variance	0.002	0.084	0.078	0.052	0.012	0.002
Total common demerits	gutted	2.26	6.40	9.76	11.82	13.79	15.75
	uncut	2.84	7.16	10.94	11.16	13.77	13.77
	variance	1.399	2.405	5.83*	1.86	0.003	16.646*

* Indicates there is a significant difference between the two means ($P<0.05$)

Skin appearance

There were no significant differences between the two treatments for skin appearance until the end of storage. In fish, skin colour usually starts to fade after 5-10 days in ice (Liston, 1980). Spanish mackerel did not lose colour until much later and could only be described as becoming dull after 18 days. The skin does mark easily during handling and will readily show line and net marks from capture. This can be used as a marketing tool as net caught fish are usually of poorer quality to line caught fish due to the delay in chilling after death. The retention of natural colouring for so long means a fresh looking fish can be presented for sale after shipment.

Loss of skin/scales

This parameter relates to how easy the skin is damaged with handling. The scales of Spanish mackerel are quite small when compared to demersal species and easy to remove. The progression of demerit points for loss of skin/scales during storage was similar to that observed for the skin appearance. Significant differences between the two treatments were only detected at the later stages of storage (days 18 and 25). If handled carefully, the loss of skin and scales from Spanish mackerel could be expected to be less for commercial shipments as the fish in this investigation were exposed to excessive handling during sample evaluation.

Skin & flesh texture

The demerit points for skin and flesh texture showed little difference between the two treatments until the end of storage. At this stage both fish were soft but the gutted fish rated a significantly higher score. This attribute is affected in the first part of the storage trial by the rigor contraction and latter by enzymic action within the muscle tissue. It took 11 days storage in ice before orange roughy flesh became soft enough to retain finger indentation (Scott et al., 1986). Spanish mackerel took up to 14 days to reach this stage.

Slime
The amount of slime on the surface of the fish during storage increased in score for both treatments at the same rate as the skin and flesh texture. The uncut fish again had a significantly lower score at the end of storage. By this stage fish from both treatments exhibited more slime than is acceptable. This parameter is associated with the growth of bacteria on the surface of fish. The progression of the bacterial load of the flesh does show a similar trend. The condition of mackerel was much better after 25 days in ice than that found with orange roughy at 16 days (Scott et al., 1986). Liston (1980) states that most fish are very slimey after 14 days in ice.

Stiffness
Stiffness was the subjective version of the mechanical rigor measurements. It contained a scale from 0 to 2 rather than a percentage and the demerit scores obtained for this parameter are shown in Table 5. Although the K values were the same for both treatments, the uncut Spanish mackerel started to soften before the headed and gutted fish. The significant difference in scores obtained after two days of storage are reflected in difference between the rigor indicies for each treatment (Figure 3). At this time the headed and gutted fish were firmer. All of the fish progressed into postrigor between two and six days and there was no significant difference between treatments from this time till the end of storage. The discussion about stiffness would be the same as that presented for rigor condition This method is not as sensitive as the mechanical technique but is used to quickly screen large numbers of fish rapidly. The data obtained for stiffness does reflect the experience of the panel used in scoring the fish.

Flesh (Cross section)
The demerit points for the appearance of a cross section of the raw flesh from mackerel during ice storage contained no significant differences between treatments. The flesh remained transluscent for two days then exhibited a constant increase for both treatments during storage until day 22, when it peaked (Table 5). The changes in flesh appearance are due to enzymic damage to the muscle protein and can be related to textural changes (Liston, 1980). The linear change during storage indicates a low level of enzyme activity present and corresponds with the steady changes in the other parameters.

Odour
The odour of the cooked flesh was similar for both treatments all through storage. The final odour scores for any fish were low during storage and could not be described as being off. The raw odour of the gills and vent of uncut mackerel behaved in a similar manner. The panel identified none of the cooked odours that Faughn's mackerel have been described as producing (Barile et al., 1985).

Flavour
The Spanish mackerel in this study did not exhibit unacceptable flavour characteristics until day 25. The flavour scores shown in Table 5 indicate that Spanish mackerel are acceptable for an extended period of time. There is a gradual loss of sweetness until the flavour becomes neutral, after day 18. There is some further deterioration but a spoilt flavour did not become apparent until the end of

storage. After 25 days the gutted fish did have a significantly higher mean flavour score than the uncut fish but there was little difference in the flavours. Headed and gutted orange roughy had been reported to retain acceptable flavour longer than whole fish (Scott et al., 1986).

The limit of acceptability for Faughn's mackerel was 15 days in ice when rejectable sour and fishy flavours developed (Barile et al., 1985). The shelf life of headed and gutted orange roughy was between 13 and 16 days while that of whole fish was between 11 and 13 days (Scott et al., 1986). In Australian North West Shelf species, off-flavours did not reach a moderate level until after 23 days ice storage (Bremner et al., 1988). The pH of Spanish mackerel did not drop below 6 even when bacterial levels become high. This would help explain why mackerel can retain an acceptable taste for such a long time and could also help restrict excessive histamine production.

Texture

The texture of Spanish mackerel in this study deteriorated slowly and only became gummy after 14 days in ice. This change had not progressed further to the soft texture normally caused by breakdown of tissue protein, by the end of storage (Table 5). There was no significant difference between the textures of whole and headed and gutted Spanish mackerel at any stage of storage. This was also found for these two product forms in orange roughy where the texture did not change after 13 days storage in ice (Scott et al., 1986). Comparative studies of the texture of different species of fish have found quite different textural traits (Cardello et al., 1982). Most species of fish develop soft texture after 10-14 days in ice (Liston, 1980). Faughn's mackerel develop dry and fibrous textures during ice storage (Barile et al., 1985). Acceptability of the texture of North West shelf species decreased with time (Bremner et al., 1988).

Total common demerits

The total demerit points for all of the parameters scored could not be compared between treatments because of the different number and type of categories evaluated. The demerit points for all of the characteristics that the two treatments have in common have been combined and are present in Table 5. The only times that there were significant differences between the two treatments during storage in ice was at day 14 , when the headed and gutted mackerel had lower scores and at day 25,when the uncut mackerel had lower scores. These differences numerically represent only a fraction of the total scored on these days. During storage the total common demerit points exhibited a similar trend to the bacterial load and K value. This occured for both treatments.

CONCLUSION

Spanish mackerel retained good quality for up to 14 days when stored in ice. The bacterial load for both treatments reached 10^5 cfu/g by day 18. The pH of Spanish mackerel did not drop below 6 even when bacterial levels become high. This would help explain why mackerel can retain an acceptable taste for such a long time and would also help restrict excessive histamine production. Spanish mackerel does not appear to suffer from enzymic damage as much as other types of fish and this might be the reason for the slow changes in the flesh. While both forms of mackerel were acceptable for a long time, the demerit scores for many of the quality indicators became less acceptable after 14 days storage time.

REFERENCES

Ando, M., Banno, A., Haitani, M., Hirai, H., Nakagawa, T. and Makinodan, Y. 1996. Influence on post-mortem rigor of fish body and muscular ATP consumption by the destruction of spinal cord in several fishes. Fisheries Science 62 (5):796-799.

AOAC. 1980. Official methods of analysis, 13 ed.Association of Official Analytical Chemists, Washington DC.

Australian Standard. 1991. General procedures and techiques (Colony count) Surface spread method. Standards Association of Australia AS-1766.1.4.

Barile, L.E., Milla, A.D. Reilly, A. and Villadsen, A. 1985. Spoilage patterns of mackerel (*Rastrelliger faughni* Matsui) 1. Delays in icing. ASEAN Food J. 1 (2):70-77.

Bito, M, Yamada, K, Mikumo, Y and Amano, K. 1983. Studies on rigor mortis among some varieties of fish by modified Cutting's method. Bull. Tokai Reg. Res. Lab., No 109:89-96.

Boyd, N.S. and Wilson,N.D. 1978. A refrigerated sea water plant for small boat application. FAO Indo-Pacific Fishery Commission, Symposium on fish utilization technology and marketing in the IPFC region, Manila:1-7.

Boyd, N.S., Wilson, N.D., Jerrett, A.R. and Hall, B.I. 1984. Effects of brain destruction on post harvest muscle metabolism in the fish Kahawai (*Arripis trutta*). J. Food Sci. 49:177-179.

Bremner, H.A., Olley, J., Statham, J.A. and Vail, A.M.A. 1988. Nucleotide cataboloism: Influence on the storage life of tropical species of fish from the North West Shelf of Australia. J. Food Sci. 53 (1):6-11.

Cardello, A.V., Sawyer, M.F., Maller, O. and Digman, L. 1982. Sensory evaluation of the texture and appearance of 17 species of North Atlantic fish. J. Food Sci. 47:1818-1823.

Ehira, S. and Uchiyama, H. 1974. Freshness-lowering rates of cod and sea bream viewed from changes in bacterial count, total volatile base- and trimethylamine-nitrogen, and ATP related compounds. Bull. Jap. Soc. Sci. Fish. 40 (5):479-487.

Gram, L., Trolle, G. and Huss, H.H. 1987. Detection of specific spoilage bacteria from fish stored at low (0°C) and high (20°C) temperatures. Int. J. Food Micro. 4:65-72.

Huynh, MD, Mackay, J & Gawley, R. 1992. Freshness assessment of Pacific fish species using K-value, in Bligh, EG (ed). Seafood Science & Technology, Fishing News Books, Blackwell Scientific Publications Ltd., Oxford: 258-267.

Iwamoto, M and Yamanaka, H. 1986. Remarkable differences in rigor mortis between wild and cultured specimens of the red sea bream *Pagrus major*. Bull. Jap. Soc. Sci. Fish. 52 (8):275-279.

Iwamoto, M, Yamanaka, H, Watabe, S. and Hashimoto, K. 1987. Effect of storage temperature on rigor mortis and ATP degeneration in plaice *Paralichthys olivaceus* muscle. J. Food Science 52 (6):1514-1517.

Izquirdo-Pulido, M.L., Hatae, K. and Haard, N.F. 1992. Nucleotide catabolism and changes in texture indicies during ice storage of cultured sturgeon, *Acipenser transmontanus*. J. Food Biochem. 16 (3):173-192.

Liston, J. 1980. Fish and shellfish and their products in Microbial ecology of foods Volume II Food commodities, eds Silliker, J.H., Elliott, R.P., Baird-Parker, A.C., Bryan, F.L., Christian, J.H.B., Clark, D.S., Olson, J.C. and Roberts, T.A. Academic Press, London:567-605.

Middlebrooks, B.L., Toom, P.M., Douglas, W.L., Harrison, R.E. and McDowell, S. 1988. Effects of storage time and temperature on the microflora and amine development in Spanish mackerel (*Scomberomorus maculatus*). J. Food Sci. 53 (4):1024-1029.

Mochizuki, S and Sato, A. 1994. Effects of various killing procedures and storage temperatures on post-mortem changes in the muscle of horse mackerel. Nippon Suisan Gakkaishi 60 (1):125-130.

Oka, H., Ohno, K. and Ninomiya, J. 1990. Changes in texture during cold storage of cultured yellowtail meat prepared by different killing methods. Nippon Suisan Gakkaishi 56 (10):1673-1678.

Sato, T., Fujii, T., Masuda, T. and Okuzumi, M. 1994. Changes in numbers of histamine-metabolic bacteria and histamine content during storage of common mackerel. Fisheries Science 60 (3):299-302.

Sikorski, Z.E. and Sun Pan, B. 1994. Preservation of seafood quality in Seafoods: Chemistry, processing technology and quality. eds Shahidi, F. and Botta, J.R., Blackie Academic and Professional, London:168-195.

Scott, D.N., Fletcher, G.C., Hogg, M.G. and Ryder, J.M.. 1986. Comparison of whole with headed and gutted orange roughy stored in ice: sensory, microbial and chemical assessment. J. Food Sci. 51 (1):79-83, 86.

Slattery, S.L. 1995. Report on tour of Hong Kong and Taiwan Importers and Manufacturers of dried seafood. 18-26 August in Evaluation of the Market for Dried Seafood by Naidoo, R.J., Slattery, S.L. and Bremner, H.A. report for FRDC Project 94/123.

Stone, H., Sidel, J., Joel, O.S., Woolsey, A. and Singleton, R.C. 1974. Sensory evaluation by quantitative descriptive analysis. Food Technol. 28 (11):24-34.

Stroud, G.D.. 1969. Rigor in fish, the effect on quality. Torry Advisory Note No. 36.

Taylor, S.L. 1988. Marine toxins of microbial origin. Food Technol. 42 (3):94-98.

Ward, D.R. 1994. Microbiological quality of fishery products, in Fisheries Processing, Biotechnical applications ed. Martin, A.M., Chapman and Hall, London:1-17.

Williams, D.J., Nottingham, S.M., Poole, S.E. & Petroff, M. 1993. Nucleotide degradation profiles of iced barramundi (*Lates calcarifer*) and Nile perch (*Lates niloticus*) muscle. J. Aquatic Food Product Technol. 2 (2):63-74.

Wells, R.M.G. 1987. Stress responses imposed by fish capture and handling: a physiological perspective. Food Technology in Australia 39 (10):479-481.

APPENDIX 1

Figure 1 Demerit sheet for uncut Spanish mackerel

TREATMENT **UNCUT**　　　　TASTER

DATE SAMPLED　　　　TAG NUMBER

SKIN APPEARANCE		V.Bright / Bright / Sl. Dull / Dull 0 1 2 3
LOSS OF SKIN / SCALES		None / Slight / Excessive 0 1 2
SKIN & FLESH TEXTURE		Firm / Soft 0 1
SLIME		Absent / Sl. Slimy / Slimy / V. Slimy 0 1 2 3
STIFFNESS		Pre-Rigor / In Rigor / Post-Rigor 0 1 2
EYES	Clarity	Clear / Sl. Cloudy / Cloudy 0 1 2
	Shape	Convex / Flat / Concave 0 1 2
	Iris	Visible / Not Visible 0 1
	Blood	No Blood / Sl. Bloody / V. Bloody 0 1 2
GILLS	Colour	Characteristic / Sl. Faded / Faded 0 1 2
	Mucous	Absent / Moderate / Excessive 0 1 2
	Smell	Fresh Fish / Neutral / Stale / Spoilt 0 1 2 3 (Fresh , Seaweed , Oily , Metallic)
BELLY	Discoloration	Absent / Detectable / Moderate / Excessive 0 1 2 3
	Firmness	Firm / Soft / Burst 0 1 2
VENT whole fish	Condition	Normal/ Sl. Break /Opening /Exudes Excessively 0 1 3 4
	Smell	Fresh / Neutral / Stale / Spoilt 0 1 2 3
FLESH (Cross section)		Transluscent / Dull 0 1
TASTE	Odour	No off odours./.Neutral / Off odour 0 1 2
	Flavour	V. sweet / Sweet / Neutral / Spoilt 0 1 2 3
	Texture	Chewy / Gummy / Soft 0 1 2

Figure 2 Demerit sheet for headed and gutted Spanish mackerel

TREATMENT **GUTTED** TASTER

DATE SAMPLED TAG NUMBER

SKIN APPEARANCE		V.Bright / Bright / Sl. Dull / Dull 0 1 2 3
LOSS OF SKIN / SCALES		None / Slight / Excessive 0 1 2
SKIN & FLESH TEXTURE		Firm / Soft 0 I
SLIME		Absent / Sl. Slimy / Slimy / V. Slimy 0 1 2 3
STIFFNESS		Pre-Rigor / In Rigor / Post-Rigor 0 1 2
BELLY CAVITY	Stains	Opalescent / Greyish / Yellow-Brown 0 I 2
	Blood	Red / Dark Red / Brown 0 1 2
FLESH (Cross section)		Transluscent / Dull 0 1
TASTE	Odour	No off odours / Neutral / Off odour 0 1 2
	Flavour	V. sweet / Sweet / Neutral / Spoilt 0 1 2 3
	Texture	Chewy / Gummy / Soft 0 1 2

Figure 3. Mean and standard error of rigor index for Spanish mackerel stored in ice.