Prevention of beetle infestation of dried fish

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Abstract

Dried fish is subject to significant insect infestation during storage, principally from *Dermestes maculatus*. In many countries where dry fish is processed, those storing the product either do not use protectants or they use cheap toxic chemicals. During a survey of insecticide usage throughout Bangladesh all 200 samples contained DDT, with many above 50 mg/kg.

To identify safe alternative compounds, trials were conducted in Senegal and Tanzania, during which dried fish were dipped into diluted solutions or pyrethroid or organophosphorous insecticides and stored for six months. Deltamethrin was particularly effective in maintaining fish quality, as it exhibited repellency; it also killed those larvae which did manage to attack the fish. The organophosphorous compounds, including etrimphos and chlorpyrifos-methyl, provided good protection but were not repellent.

Pirimiphos-methyl, which is approved for use on dried fish, and other compounds which are used for treating grain, would provide effective alternatives to the toxic chemicals now in use. Recent surveys suggest that some plant materials which are used traditionally as fish protectants, such as *Boscia senegalensis*, could be used to supplement the activity of conventional insecticides, or might even eliminate the need for their use.

Introduction

Insect infestation is an important cause of economic and physical losses in the cured fish industries of developing countries (Poulter et al. 1988). Dried fish and fish products are often infested by beetles, principally of the genus *Dermestes*, during transportation or storage. Losses of dried fish have been variously estimated at up to 50% (e.g. Rollings and Hayward 1963; Guillon 1976). More recent quantitative estimates suggest levels of 10–20% may occur after 6 months in store (Awoyemi 1991; Golob et al. 1987). Beetle damage may also cause significant losses in quality of stored fish, often rendering the product unfit for human consumption.

There are various methods by which dried fish may be protected against beetle damage. In some countries, cheap domestic and agricultural insecticides are used by fish processors and sellers. Frequently, however, extremely hazardous compounds are employed which are dangerous to consume. For example, recent studies of insecticide use during fish processing in Bangladesh showed that many traders were treating with either DDT (A. Ward, pers. comm.) or dichlorvos (D.J. Walker, pers. comm.), both of which are too toxic for this purpose.

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During the last decade, work in the Gambia, Malawi and the U.K. (reviewed by Walker 1987) has resulted in the establishment of an international standard by the FAO/WHO Joint Meeting on Pesticide Residues (JMPR) for use of a safe insecticide treatment. A maximum residue limit (MRL) of 10 mg/kg has been set for pirimiphos-methyl on dried fish, though this was principally the result of research to control blowflies on drying fish.

Pirimiphos-methyl is the second insecticide to be approved for application to fish. In East Africa, naturally-occurring pyrethrins are used as dried fish protectants. These compounds have JMPR approval for use on fish. In Kenya, where the source plants, *Chrysanthemum cinnerarifolium*, are cultivated, Gjerstad (1989) has shown that cost-effective treatments can be undertaken. However, Gjerstad's treatments exceeded the JMPR recommended MRL. Furthermore, pyrethrins are relatively unstable in daylight and are also expensive to produce and market, particularly in countries where the plants cannot be cultivated.

Clearly, there is a need to add to the list of approved chemical insecticides to ensure that the processors and people storing dried fish have ready access to compounds which are safe, effective and readily available. The reliance on just two chemicals does not allow these criteria to be adequately met. In order to provide alternatives, experiments have been undertaken in Kenya, Tanzania and Senegal so that candidate compounds could be identified. A summary of this research follows.

Conventional Insecticides for Beetle Control

Experiments both in the laboratory (Taylor and Evans 1982) and in Kenya (Golob et al. 1987) have demonstrated that *Dermestes* species can be controlled by applying relatively safe pyrethroid and organophosphate insecticides which have been approved by JMPR and the Codex Alimentarius Commission for use on cereal and pulse grains (Anon. 1982). However, the field work in Kenya was undertaken in the very hot, dry area close to Lake Turkana, under climatic conditions which are not experienced in most areas of the world where dried fish are stored. Similar trials were therefore undertaken in climates in Tanzania and Senegal in order to simulate more typical conditions; the observations recorded are illustrated below for the experiments undertaken in Senegal.

Methods

The experiment was carried out in a large store room at Yoff, near Dakar, Senegal (rainfall and relative humidity are shown in Fig. 1). The fish, *Plectorhinchus mediterraneus* (local name, Daurade Grise), were split down the mid-line, gutted and air-dried. Each fish was 30–35 cm in total length and weighed 140–170 g. Approximately 700 kg of dried fish were heaped and batches of 18 fish were selected at random for each replicate. Insect infestation was very low. Nevertheless, all

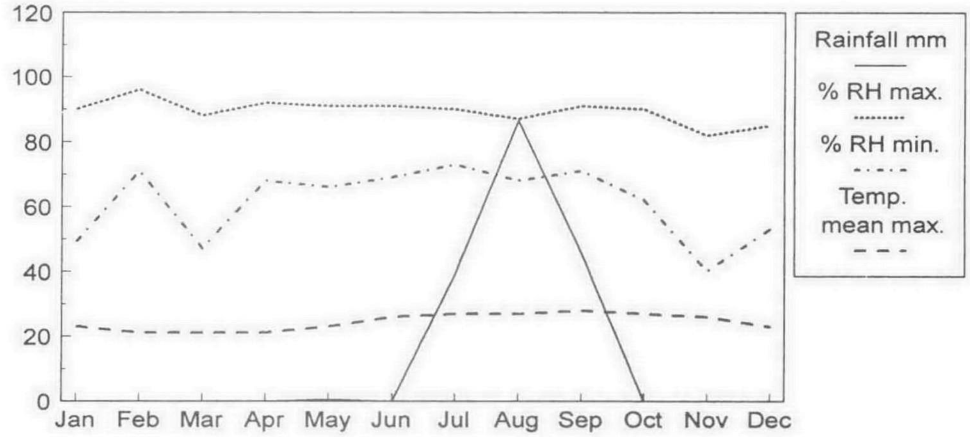

Fig. 1. Climatic data for Yoff, Dakar, Senegal 1993.

insects were removed from the fish immediately before treatment.

Fish were either dipped into or sprayed with dilute solutions of insecticide, or water for the control. Fish were dipped in pairs for five seconds in 10 L solutions of insecticide diluted in fresh water, in plastic bowls of 25 L capacity. After the treated fish were shaken free of excess liquid and allowed to drain in the open for a further 15–30 minutes, they were tied into bundles and placed in the store, on a wire-mesh rack which raised the fish 8 cm above the floor.

Water-based sprays were applied with a 1.5 L capacity, hand-operated pressurised sprayer (Hozelock Polyspray 2), using a standard nozzle producing a cone jet. Only one side (internal body wall) of the fish was sprayed. After a drying period of 15 minutes, the fish were tied into a bundle, arranged so that an untreated surface was in contact with a treated one.

Each treatment was replicated five times, and each control four times. One replicate of each treatment was reserved for analysis of residues of active ingredients. The trial was laid out in a 8 × 18 grid on four rows of racks. The position of each replicate was selected randomly.

Treated replicates were examined for signs of infestation and, at the end of a three-day equilibration period, were weighed to obtain a initial undamaged wet weight. Each replicate was seeded with two adult *Dermestes* (either *D. maculatus* or *D. frischii*) and three larvae. Fish were re-examined at approximately six-weekly intervals when wet weights were measured, insect numbers recorded and the numbers of beetle-damaged fish counted. At these sampling occasions 10 randomly selected fish were analysed for water activity and two fish from each replicate were removed for residue analysis.

In Tanzania, trials were conducted in Mwanza, at the southern end of Lake Victoria, using smoked-dried Nile perch, *Lates niloticus*. Insecticides were applied with a Cooper Pegler Falcon 5 pressurised sprayer fitted with a flat fan 000 nozzle. At each sampling occasion the parameters measured were as described above.

Results

In both Senegal and Tanzania much of the active ingredient was lost during application or was quickly degraded. Fish dipped in insecticide retained much more of the nominal active ingredient and these treatments degraded much more slowly. Table 1 illustrates the residues found in the Senegal experiment.

As a consequence of the poor retention of active ingredient none of the spray treatments, except those employing deltamethrin, provided control of larvae. All dip treatments provided some control for 8 weeks and many did for 12 weeks. With the exception of the treatments with permethrin, all fish dipped in the higher dosages of the solutions provided excellent control of *Dermestes* larvae for the entire 24-week period (Fig. 1). Protection provided by the lower dosages of the dip solutions was almost as effective.

The increase in insect damage in fish samples throughout the trial in Senegal is shown in Table 2. More than three-quarters of all the control samples were damaged within two months. Of the dipped fish, only those treated with permethrin exhibited the same rate of increase. Other replicates, with the exception of those treated with the lower dosages of pirimiphos-methyl, remained relatively lightly damaged until the final sampling occasion. The mixture of deltamethrin and pirimiphos-methyl appeared to be particularly effective in preventing damage.

Dip treatments using deltamethrin provided good control throughout the storage trial. There were, in general, fewer live adults on treatments containing deltamethrin than on other treatments. This was not reflected in an increase in dead adults but rather by the ability of deltamethrin to repel *Dermestes*. This effect was recorded in trials both in Kenya (Golob et al. 1987) and in Mali (Duguet et al. 1985) where synergised deltamethrin was used (Fig. 2.).

The organophosphates used in the Senegal trial, etrimphos, pirimiphos-methyl and chlorpyrifos-methyl, all gave good control of beetle populations throughout the trial (Fig. 2.). There did not appear to be any advantage to be gained by using mixtures of pirimiphos-methyl with a pyrethroid.

Other Methods

The use of any synthetic chemical must inevitably result in detrimental effects. Although fish treated with chemicals approved by JMPR are safe to ingest if the treatments are undertaken correctly, there will be drawbacks. For example, although the chemicals degrade rapidly there may be some environmental consequences before this occurs. Pyrethroids such as deltamethrin are highly toxic to fish (LD50 0.001 mg/L) and, if accidentally introduced into water courses, may lead to poisoning. Continued use or misuse of a chemical will also lead to the development of resistance by the target pest insect to that insecticide, an event which is all too common in the agriculture and public health sectors. Thus, there is a need to identify alternative methods of protecting dried fish which do not rely exclusively on the use of synthetic insecticides.

A number of methods have been used, or have been investigated experimentally, to control insect infestation in fish and

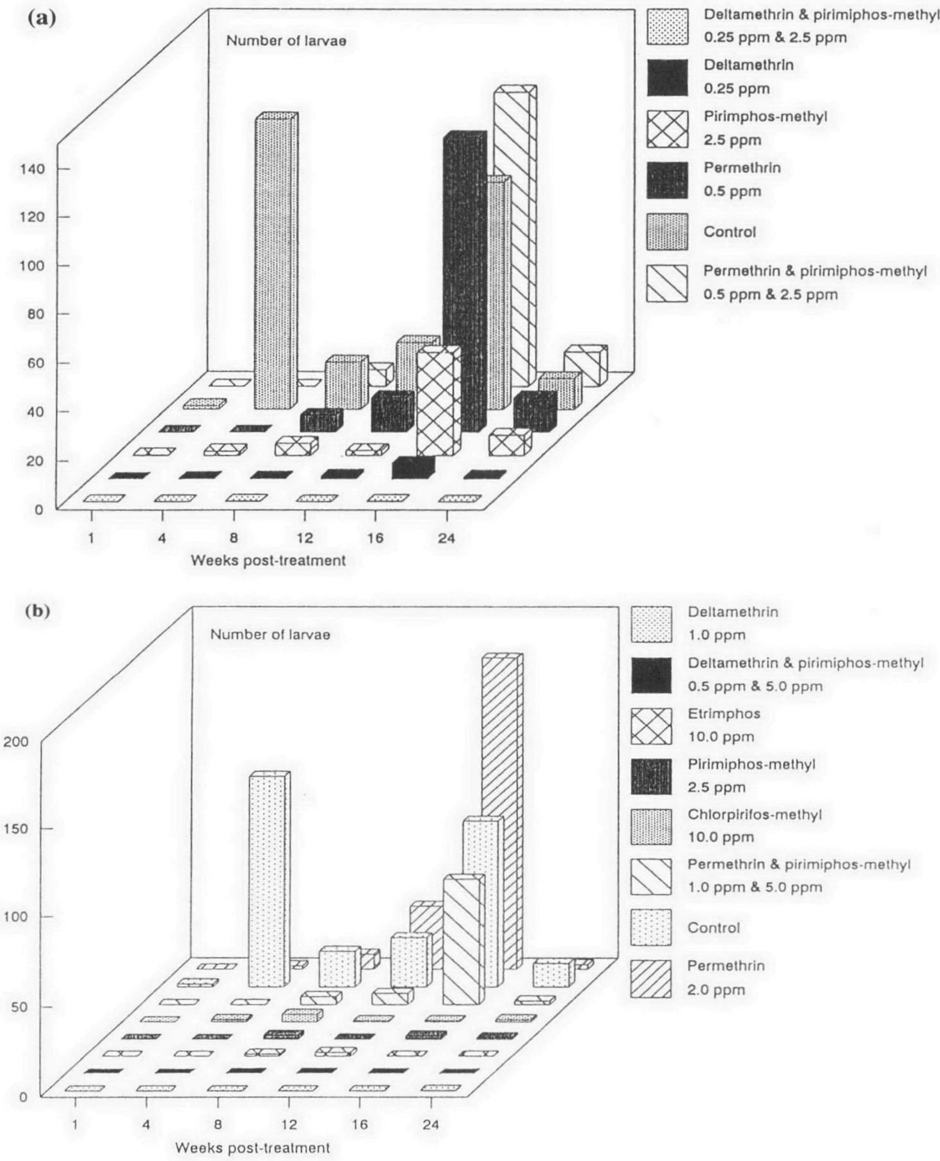

Fig. 2. The numbers of live *Dermestes* larvae found on samples of fish dipped in the (a) lowest and (b) highest dosages of insecticide solutions.
Note: Only a single dosage of chlorpyrifos-methyl and etrimphos were tested. Each column represents the mean of four replicates.

fish products. These include the application of salt (Osuji 1975), smoking and the application of heat (Proctor 1977; Curran and Trim 1982), irradiation (Ahmed et al. 1978), packaging in polythene and other containers (Proctor 1977) and screening (Esser 1991). However, for various reasons, including socioeconomic, technical or marketing factors, it has generally been impractical to rely solely on non-chemical practices for adequate control of infestations.

Plants and plant extracts

There are numerous examples of the use of plants or plant extracts as protectants of stored agricultural produce (Golob and Webley 1980; Rees et al. 1993). As a result of a recent survey (Ward and Golob, unpublished data) the use of such materials as additives to fish during and after processing was identified.

Leaves of *Azadirachta indica* (neem) have been used in the Sorogon region of the Philippines to protect dried roundscad, mackerel and thread fin bream. The leaves are spread along the foot of walls and in the corners of stores. Similarly, in Senegal processors place jute bags containing leaves beneath dried fish during storage. The indirect application of neem by these means might be acceptable to consumers of fish because it alleviates the potential taint problems which might be caused by direct application; Okorie et al. (1990) found a bitterness in taste from using neem seed which might be removed by boiling, and Mathen et al. (1992) reported that neem oil, which repelled beetles, had a nauseating, objectionable odour which was imparted to both fish and its packaging. Okorie et al. (1990) made the observations during experiments which showed that oviposition of *Dermestes maculatus* could be prevented in dried tilapia if the fish was treated with 2–8% dried leaf powder. Such a treatment also had larvicidal effects.

Vegetable and fish oils are used in West Africa as protectants. Nigerian fish merchants rub groundnut and other vegetable oils on dried fish for either protective or cosmetic effects (Don Pedro 1989, 1990). A similar practice is undertaken in Senegal where fermented fish, after drying, is coated with fish liver oil. This practice may simply be to enhance

Table 1. Insecticide residues found in fish samples during storage[a].

Treatment	Nominal concentration (mg/kg)	Duration of storage (weeks)					
		1	4	12	1	4	12
		Dip treatments			Spray treatments		
Deltamethrin	0.25	0.18(72)	0.21	0.55	0.14(56)	0.15	0.18
	0.50	0.40(80)	0.36	0.36	0.19(38)	0.19	1.10
	1.00	0.64(64)	0.69	0.40	0.39(39)	0.73	0.16
Permethrin	0.50	0.48(96)	0.70	0.78	0.29(58)	0.22	0.15
	1.00	1.01(101)	0.99	0.94	0.48(48)	0.42	0.12
	2.00	1.74(87)	1.22	1.75	0.72(36)	0.86	0.72
Pirimiphos-methyl	2.50	0.54(22)	0.79	0.40	0.79(32)	0.21	0.10
	5.00	3.35(67)	1.00	0.10	0.87(17)	0.49	0.01
	10.00	6.60(66)	3.50	1.48	2.60(26)	1.26	0.01
Chlorpyrifos-methyl	10.00	6.38(64)	3.79	0.92	2.21(22)	0.43	0.22
Etrimphos	10.00	11.25(112)	5.75	4.35	4.75(48)	3.75	1.50
Deltamethrin	0.25+	0.30(120)	0.14	0.22	0.06 (24)	0.06	0.04
+ pirimiphos-methyl	2.50	1.39(56)	0.60	0.11	0.35(14)	0.25	0.07
	0.5+	0.58(112)	0.20	0.24	0.24(48)	0.18	0.15
	5.00	2.00(40)	0.84	1.04	0.42(8)	0.49	0.14
Permethrin +	0.5+	0.51(102)	0.41	0.43	0.31(62)	0.24	0.21
pirimiphos-methyl	2.50	3.10(124)	1.85	0.25	0.52(21)	0.31	0.02
	1.0+	0.85(85)	0.85	1.11	0.42(42)	0.33	0.18
	5.00	5.05(101)	3.96	0.52	0.72(15)	0.67	0.07

[a]Data are means of two replicates
Different fish were analysed at each occasion
Data in parentheses represent the residues after 1 week as a percentage of the nominal dosage.

Table 2. Number of fish exhibiting insect damage (%)[a].

Treatment	Nominal concentration (mg/kg)	Duration of storage (weeks)					
		1	4	8	12	16	24
		Dip treatments					
Deltamethrin	0.25	0	0	3	15	26	57
	0.50	0	0	0	8	13	33
	1.00	0	4	3	8	7	28
Permethrin	0.50	1	33	78	76	94	99
	1.00	0	21	58	88	94	99
	2.00	1	8	28	64	64	86
Pirimiphos-methyl	2.50	0	15	25	50	51	67
	5.00	0	6	14	24	38	74
	10.00	0	4	19	35	24	31
Chlorpyrifos-methyl	10.00	0	4	26	38	31	51
Etrimphos	10.00	0	0	11	11	29	26
Deltamethrin +	0.25+2.5	0	0	0	3	1	4
Pirimiphos-methyl	0.5+5	0	0	0	1	10	8
Permethrin +	0.5+2.5	0	0	22	42	61	51
Pirimiphos-methyl	1+5	0	6	31	57	72	65
Control		2	63	83	90	90	93

[a]Data represent the mean of four replicates

appearance because J. Wood (pers. comm.) found traders in retail markets sprinkled the oiled fish with pepper and salt to provide protection against beetle damage. Don Pedro (1989, 1990) undertook laboratory experiments to assess the affect of groundnut, coconut, palm and shark liver oils on *D. maculatus*. Only very heavy applications to fillets of dried trout, 112 mL/kg, had a significant affect on progeny development; these quantities would thoroughly douse the fish and be impractical. In other experiments, Mathen et al. (1992) examined the repellency of cashew nut shell liquid and oils of coconut, neem, palm, gingelly, mustard, sunflower, safflower, castor seed, rice bran and groundnut when applied to dried silver belly. Mustard oil-treated fish were most repellent, remaining insect free after 40 days. Some repellency was observed against blowflies in particular and to a limited extent against beetles. However, the lack of information in this paper, especially regarding application rates and insect species tested, requires the observations reported to be verified.

Peppers have also been reported to be used as protectants but against blowflies. For example, Rollings and Hayward (1963) mentioned that in some Chad fishing villages a small proportion of the catch is set aside for local consumption. This fish, either Nile or Niger perch, is commonly descaled, filleted and rubbed with peppers before sun drying.

In Senegal, leaves of *Boscia senegalensis* are placed in layers between fish to provide protection against *Dermestes* species. This evergreen shrub occurs throughout the Sahel. Mali fishermen in remote areas of the Niger delta use a coarse powder of *B. senegalensis* leaves mixed with *Capsicum fructescens* fruit to protect smoke-dried fish.

The information on the practical use of plant material for controlling beetle infestation of dried fish is sparse. Equally limiting is experimental evidence. Other than the experiments mentioned above some work has been undertaken by Don Pedro (1985) to investigate the potency of citrus fruit peels. A degree of control was obtained by application of 14% orange (*Citrus sinensis*) peel which resulted in 50% mortality of *Dermestes* adults after seven days.

Conclusion

Pirimiphos-methyl, currently recommended for protection against blowfly attack, would provide effective protection against beetle damage in store for up to 6 months when applied to give the MRL of 10 mg/kg. Other OPs which are approved for use on raw cereals could be used in the same way. Dried fish will remain in best quality, with fewest signs of insect damage, if treated with deltamethrin. This insecticide should be used to give 0.25 mg/kg for storage of four months or less; for longer storage the application rate should be doubled. However, deltamethrin and the other alternatives to pirimiphos-methyl must be recognised internationally for use as dried fish protectants.

It is clear that plants may have the potential to protect dried fish against beetle damage but that much more work is required to identify active materials. The dearth of plants used for this practice necessitates a search for candidates in other areas of pest management. The applicability of botanicals as protectants for grain storage would provide indicators to plants which might be assessed, as they too would be required for application to food.

References

Ahmed, M., Bhuiya, A.D., Alam, A.M.S. and Huda, S.M.S. 1978. Radiation disinfestation studies on sun-dried fish. Proceedings Indo-Pacific Fishery Commission, Manila, Philippines, 8–17 March 1978, 18, 310–321.

Anon. 1982. Pesticide residues in food—1981. FAO Plant Protection and Production Paper No. 37, 22–25.

Awoyemi, M.D. 1991. Preliminary observations on the incidence of insect pests and related damage to stored dried fish in Kainji Lake area. Insect Science and Its Applications, 12, 361–365.

Curren, C.A. and Trim, D.S 1982. Comparative of solar and sun drying of fish. In: James, D., ed., The production and storage of dried fish. Proceedings of Workshop on Production and Storage of Dried Fish, Universiti Pertanian Malaysia, Seradang, November 1982. FAO Fisheries Report, 279, 69–80.

Don Pedro, K.N. 1985. Toxicity of some citrus peels to *Dermestes maculatus* Degeer and *Callosobruchus maculatus* (F). Journal of Stored Products Research, 21, 31–34.

Don Pedro, K.N. 1989. Insecticidal activity of some vegetable oils against *Dermestes maculatus* De Geer (Coleoptera: Dermestidae) on dried fish. Journal of Stored Products Research, 25, 81–86.

Don Pedro, K.N. 1990. The effect of fixed vegetable and animal oils on the feeding and development of *Dermestes maculatus* De Geer (Coleoptera: Dermestidae) larvae on dried fish. Journal of African Zoology, 104, 23–28.

Duguet, I.S., Brou Bleou, C., Tamboura and Djenepo 1985. Evaluation of the efficacy of deltamethrin compared with pirimiphos-methyl and tetrachlorvinphos against *Dermestes maculatus* Deg. and *Necrobia rufipes* Deg. on *Saratherodon niloticus* at Mopti (Mali). International Pest Control, 27, 92–99.

Esser, J.R. 1991. Biology of *Chrysomya megacephala* (Diptera: Calliphoridae) and reduction in losses caused to the salt-dried fish industry in south-east Asia. Bulletin of Entomological Research, 81, 33–41.

Gjerstad, D. 1989. Prevention of infestation by *Dermestes maculatus* Degeer in East African dried fish using pyrethrum and piperonyl butoxide. Fishery Technology, 26, 25–29.

Golob, P., Cox, J.R. and Kilminster, K. 1987. Evaluation of insecticide dips as protectants of stored dried fish from dermestid beetle infestation. Journal of Stored Products Research, 23, 47–56.

Golob, P. and Webley, D.J. 1980. The use of plants and minerals as traditional protectants of stored food products. Tropical Products Institute, Report G138, 14 p.

Guillon, M. 1976. Controlling insect pests of dried fish—an experiment in Mali. SPAN 19 127–128, 134, 137, 139.

Okorie, T.G., Siyanbola, O.O. and Ebochuo, V.O. 1990. Neem seed powder as a protectant for dried tilapia fish against *Dermestes maculatus* Degeer infestations. Insect Science and Applications, 11, 153–157.

Osuji, F.N.C. 1975. The effects of salt treatment of fish on the developmental biology of *Dermestes maculatus* (Coleoptera: Dermestidae) and *Necrobia rufipes* (Coleoptera: Cleridae). Entomologia Experimentalis et Applicata, 18, 472–479.

Mathen, C., Unnikrishnan Nair, T.S. and Ravidranathan Nair, P. 1992. Effect of some vegetable oils on insect infestation during storage of dry cured fish. Fishery Technology, 29, 48–52.

Poulter, R. G., Ames, G.R. and Evans, N.J. 1988. Post harvest losses in traditionally processed fish products in less developed countries. In: Morrissey, M.T., ed., Post Harvest Fisheries Losses, Proceedings of an International Workshop, 12–16 April 1987, University of Rhode Island, USA., 133–146.

Proctor, D.L. 1977. The control of insect infestation of fish during processing and storage in the tropics. Proceedings of Conference on Handling, Processing and Marketing of Tropical Fish, 5–9 July 1986. London, Tropical Products Institute, 301–311.

Rees, D.P., Dales, M.J. and Golob, P. 1993. Alternative methods for the control of stored-product insect pests. A bibliographic database. Natural Resources Institute, Chatham, U.K., ix + 151 p.

Rollings, M.i. and Hayward, L.A.W. 1963. Aspects of the dried fish trade in Nigeria with particular reference to Lake Chad. Tropical Stored Products Information, 5, 162–167.

Taylor, R.W.D. and Evans, N.J. 1982. Laboratory evaluation of four insecticides for controlling *Dermestes maculatus* Degeer on smoke dried fish. International Pest Control, 24 42–45.

Walker, D.J. 1987. A review of the use of contact insecticides to control post-harvest insect infestation of fish and fish products. Rome, FAO Fisheries Circular No. 804, iii + 19 p.