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THE INFESTATION OF DRIED FISH BY DERMESTES SPP. IN AFRICA AND APPROPRIATE CONTROL MEASURES*

by

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ABSTRACT

Fish is subjected to several species of insect pest during drying and storage, the most important of these being certain Dermestid beetles. There are many references to considerable losses due to such infestation, and there is ample evidence to support concerted loss reduction programmes.

Chemical and non-chemical methods of controlling insect infestation are reviewed and reference is made to FAO/WHO tolerance limits on toxic residues in dried fish. The formula for effective control of insects infesting dried fish is essentially a composite one, consisting of both chemical and non-chemical methods. The importance of hygiene at all stages in the handling of fish is stressed while smoke drying and brining minimise the risk of insect infestation. Preventative measures include the wider use of fly-screens and polyethylene bags for transportation and storage.

Fumigation is suggested as a possible method of controlling Dermestid beetles in order to halt further damage as quickly as possible after drying. The use of contact insecticides of low mammalian toxicity is discussed, and further evaluation of some newer compounds, especially the synthetic pyrethroids, is suggested as being urgently needed.

INTRODUCTION

Fish is subject to infestation by several species of flies (Diptera), beetles (Coleoptera) and mites (Arachnidae, Acarina) during drying and as the dried product in storage. Proctor (1977) provides a convenient summary of these various pests and their relative importance, and points to the fact that Dermestes species (Coleoptera:Dermestidae) are the most important pests of dried fish in storage.

Three species of Dermestes are associated with dried fish in the tropics and sub-tropics: D. ater Deg., D. frischii Kug. and D. maculatus Deg.. All three species are found in Africa, but D. ater is much less common on dried fish than either of the other two species (Green, 1967; Proctor, 1972). D. frischii is normally associated with dried marine fish (Mallamaire, 1957; Green, 1967) while D. maculatus is commonly associated with dried freshwater fish (McLellan, 1964; Proctor, 1972).

There are so many references in the literature to losses of dried fish due to insect, particularly Dermestes, infestation that it is superfluous to reiterate any of the various estimates here. Suffice to say, perhaps, that the losses are too high to be tolerated and that there is ample evidence to support the most concerted loss reduction programmes that can be organised, (National Academy of Sciences, 1978). Successful methods of controlling insect pests of drying and dried fish have been developed but their adoption is far from widespread. The main difficulty is that the greater part of the fish industry in tropical countries is conducted by small traders under relatively primitive conditions, often in remote places. The extension of new techniques in such circumstances presents formidable problems, not the least of which are the lack of trained personnel to pass on information and the reluctance of many people to adopt new ideas (Proctor, 1977).

Description of Dermestes spp. adults and larvae

The adults are moderately large oval beetles 6 to 10 mm long, densely covered with hairs or scales. D. frischii and D. maculatus adults are dark purplish brown with a broad band of white or yellowish-white hairs along each side of the pronotum, and a predominantly white abdomen (underside) with patches of black hairs at the sides. The inner apex of each elytron of D. maculatus is produced behind to form an acute spine. This characteristic can only be seen with a hand-lens, and is entirely absent in D. frischii. D. ater is somewhat lighter brown than the other two species, and does not have white markings on the pronotum; the sternites of the abdomen are more or less the same colour as the elytra but with a pale yellowish pubescence and a pattern of patches of dark brown hairs. In all three species the antennae are 11-segmented with a distinct and often quite large club.

For all practical purposes it is not possible to differentiate between the larvae of the three species. The body is mainly dark brown in colour with cream-coloured rings and a similarly light coloured line down the middle of the back and covered with numerous tufts of long hairs. Mature larvae can measure up to 15 mm in length.

Biology of Dermestes spp. on untreated dried fish

Dermestid infestation of fish can start during the early stages of drying. Observations suggest that the fish needs to be at least surface-dried before female Dermestes actually start laying eggs on it, although some free water is necessary for optimum oviposition (Osuji, 1975). Proctor (personal observation) noted that D. maculatus infesting split Tilapia sp. first laid eggs between the gills of the fish, gaining access through the mouth or opercula. Others (Green, 1967; Osuji, 1975) have recorded that eggs are laid in cracks or cuts (caused by gutting, splitting or dividing the fish into pieces) in the flesh. Each D. maculatus female is capable of laying more than 250 eggs, and will lay most of them between 3 and 11 days after emergence (Osuji, 1975).

Eggs hatch within 1 to 6 days of being laid, depending upon temperature (Azab et al, 1975), and the larvae burrow straight into the flesh of the fish where they remain until they are ready to pupate. There may be up to 10 instars, depending upon the suitability of the fish as food, temperature and humidity (Azab et al, 1972). Under optimum conditions, e.g. on Tilapia sp. at 27°C and in equilibrium with 75% relative humidity (r.h.), D. maculatus larvae mature within 30 days and pass through 7 instars.

The final instar larva excavates a chamber in the fish flesh, in which it pupates. In this case, under optimal conditions, the pupal stage lasts for 10 to 12 days. If, however, the larva has been feeding on ground fish (fishmeal) it is unable to pupate as described and goes into a 4 to 7 day long pre-pupal stage during which it becomes quiescent and assumes a shortened and thickened 'C' shape before entering a true pupal stage of only 4 to 7 days duration (Osuji ,1975).

Azab et al (1972) studied the longevity of D. maculatus adults at various temperatures and relative humidities and found that longevity ranges between about 50 days (35°C and 75% r.h.) and 173 days (21°C and 75% r.h.). Longevity increases with increase in relative humidity or decrease in temperature, and females tend to live longer than males. Absence of food or water will shorten the life of the adult.

Relative susceptibilities of different genera of fish to infestation by Dermestes sp.

Information is relatively scant, but what there is suggests that different genera of fish do exhibit varying degrees of susceptibility to infestation by Dermestes spp. Appreciation of the susceptibility of fish to infestation obviously relates to its storability, and could assist in determining the type and cost of pest control measures required.

In a paper specifically concerned with susceptibility to infestation Osuji (1974) recorded that, in Nigeria, Clarias was found to be most heavily infested and Citharinus was the least liable to infestation, while Heterotis and Synodontis occupied intermediate positions, when exposed to D. maculatus. During a comparative study of different treatments for the protection of smoke-dried fish from Dermestid infestation Proctor (1972) noted that among the control (i.e. untreated) fish, Clarias very quickly acquired a moderate infestation which developed into a heavy infestation within 8 weeks, Tilapia was only marginally less susceptible, while Hydrocyon took 12 weeks to develop a heavy infestation and Synodontis was relatively resistant to infestation. In laboratory studies in Egypt Azab et al (1972) observed that D. maculatus took longer to develop and suffered slightly higher larval mortality on Sardinella than on Tilapia.

No one has yet established why such variations in susceptibility to infestation occur. A link with lipid content has been suspected, but conflicting evidence (Green 1976; Proctor, 1972; Osuji, 1974) rules out a simple relationship.

Non-chemical methods of controlling Dermestid beetles

In many fisheries and fish markets in tropical countries the high infestation risk is associated with low hygiene standards. Even the most potent control measures can be rendered ineffective in situations where sanitary conditions are poor. Therefore, the very first step that must be taken is to keep places where fish are handled as clean as possible (Watanabe and Cabrita, 1971; Aref, et al, 1974).

At the end of each day's operation the whole area in which fish have been handled, including all equipment, should be thoroughly cleaned. All fish residues should be gathered together for disposal and not left to serve as breeding grounds for insect pests. If arrangements have not been made to remove the fish residues for conversion into fertiliser, they should be buried or destroyed in an incinerator. At the fish landing it may be expedient to return waste to the open water where it can be consumed by fish and other organisms. These basic measures should be possible even in the most undeveloped fishing situations.

Buildings used as fish stores and markets are often fitted with fly-proof screens and self-closing doors. However, these protective measures are rarely employed at fisheries where screens would appear to serve a particularly useful purpose. Different kinds of screening materials are described by Blatchford (1962).

Sticky fly-traps or swats may be employed to deal with the occasional intruders into screened places. Alternatively where there is a mains electricity supply insect electrocutors could be installed.

All stages of insects, from egg to adult, are killed by temperatures in excess of 50°C (Blatchford, 19762). Szabo (1986) exploited this phenomenon in Mali by placing frames, with transparent polyethylene sides and tops, over bundles of infested dried fish weighing up to 65kg. The temperature inside these cages rose to 80°C within 30 minutes, forcing insects out through the bottom or killing them. Toye (1970) has suggested heating dried fish in simple charcoal fired ovens for 30 minutes at four day intervals during the storage period to control infestation. Cutting et al (1956) warn that artificially heating fish above 65 to 70°C may cause scorching and spoil the colour or flavour of dried fish. The range of temperatures available for killing pests without spoiling fish is, therefore, very narrow and the warm smoking technique (45°C to 60°C for 4 to 7 hours for larger fish) recommended by Watanabe and Cabrita (1971) is probably the best method to adopt.

Keshvani (1964) observed that well dried fish could be stored for up to one year in sealed polyethylene bags without serious loss of quality. However, Cole (1963) found that the sharp projections of dried marine fish punctured polyethylene bags. Nevertheless, both Watanabe (1971) and Toots (1972) recommend sealing dried fish in these bags, the latter emphasizing the need to cool the fish after thorough drying and to store the product in a cool shady place to avoid sweating.

Chemical methods of controlling Dermestid beetles

Treating fish with salt (sodium chloride) during the drying process is probably the oldest method of improving their keeping quality. The primary effect of salt is bactericidal but there is no doubt that it also retards the development of insect infestations. The degree of attraction of salt treated fish to adult dermestid beetles is inversely related to the amount of initial salting (Green, 1967). Kenching, ie rubbing salt into the fish before drying, is not as effective in this respect as brining (leaving fish to soak in saturated salt solution: the saltiness of the product being determined by the size of the fish and the length of time it is left in the brine). Eggs laid by dermestid beetles on salted fish may hatch but the emerging larvae are slow to develop and suffer high mortality (Osuji, 1975). Well dried and brined marine fish will not be infested for at least six weeks (Green, 1967).

Heavily salted fish is not a universally acceptable product and, to meet the requirements of some markets (Watanabe and Dzekedzeke, 1971), the salt content has to be limited to 10% or less. At this level, some insect infestation is inevitable (Proctor, 1972).

Drying fish over smoky fires is frequently practised, the product acquiring a flavour which is preferred to that of sun dried fish. Aref et al (1965) reported from Mali that smoke drying over hardwood sawdust fires appeared to impart some protection against insect infestation. However, Conway (personal communication) observed infestation of fish after drying over smoky hardwood fires for different lengths of time in The Gambia; he concluded that it was the dryness of the product, rather than any property of the smoke, which affected insect attack.

Amorphous silica-based dusts, which are virtually non-toxic to mammals (Kane, 1967), have been tried on dried fish (Green, 1967; Proctor 1972) but were found to be ineffective because they absorbed oil from the fish. Aref et al (1965) tried sulphur dipping and fuming with equally poor results.

Chemicals in the gaseous state have the capacity to penetrate commodities being treated and so achieve rapid control of all developmental stages of insect pests present. Effective fumigation requires that the commodity to be disinfested is exposed to a sufficiently high concentration of the gas for a period long enough to obtain complete insect mortality.

Fumigation confers no lasting protection and reinfestation can take place immediately should the commodity be re-exposed to insect pests.

Two fumigants that are commonly employed to disinfest a wide variety of foodstuffs are methyl bromide and phosphine. Both these chemicals might be considered for the treatment of dried fish in order to reduce losses caused by Dermestes spp. Methyl bromide was reported as a successful fumigant of dried fish treated under gas proof sheeting in Angola (Amaro and Soares de Gourela, 1957). Mallamaire (1957) fumigated dried fish with methyl bromide under partial vacuum at a dosage rate of 80gm per cubic metre for 2 hours. At the same dosage rate, 6 hours was found to be necessary for effective fumigation of dried fish in the Cameroons under normal atmospheric pressure (Galichet, 1960). No recent reports of the use of methyl bromide to fumigate dried fish are available.

Methyl bromide vaporises at 4°C and is normally stored as a liquid under pressure in cylinders or cans. This requires that considerable expertise is necessary for the safe and effective use of the fumigant, which might therefore be considered unsuitable for use by the small scale producers under relatively primitive conditions.

Phosphine (hydrogen phosphide), is liberated from tablets, pellets or packets of an aluminium phosphide preparation which release the gas upon contact with water vapour, of which there is usually sufficient in the atmosphere. Aluminium phosphide preparations must be kept in a sealed dry state until required for use but phosphine does not require special application equipment such as is necessary when using methyl bromide. Phosphine can be employed effectively under quite primitive conditions provided the user has been trained in the safe method of use and is aware of hazards that can arise from misuse. There are no readily available reports of the use of phosphine for the disinfestation of dried fish, and no laboratory evaluations of the effectiveness of this fumigant in controlling Dermestes spp. have been noted. There is no reason to suppose that this insect pest is especially tolerant of phosphine but this data should be obtained before any meaningful trials on the disinfestation of dried fish can be undertaken. Grain is often fumigated at farm or village level using sealed metal drums or heavy gauge (127 micron) plastic sacks.

The sharp projections on dried fish might render the use of plastic sacks impractical due to the ease of puncturing, but metal drums or the use of gas proof sheets to cover sacks of dried fish could make possible the use of phosphine at the rural level. A factor to be considered regarding the use of phosphine is the minimum pack size marketed. The smallest currently available preparation of aluminium phosphide is a flask containing 30 tablets each of which liberates 1 gm of phosphine. Pellets are also available which liberate 0.2 gm of phosphine, the smallest currently available flask containing 165 of these. One sack of dried fish would probably require no more than 2-3 pellets for satisfactory fumigation, with a minimum exposure period being 3 days. Flasks are resealable and therefore present no hazard if stored in a secure dry situation but the relatively large quantities of tablets or pellets in the smallest containers marketed at present make the use of this fumigant more suited to cooperatives and other large scale producers rather than to individuals.

Immediate fumigation of fish after drying will halt any further damage by insect pests such as Dermestes spp. If reinfestation can be prevented losses could be reduced to a minimum. Fumigation as a method of loss reduction in dried fish deserves more attention than has been given hitherto; phosphine should certainly be investigated as an alternative to methyl bromide.

Long term protection of dried fish or other infestible foodstuffs can be provided by chemicals which remain active over a prolonged period. Such insecticides must be sufficiently toxic to the insect pests present, but not harmful to the final consumer of the foodstuff. There are no insecticides which satisfy these two requirements perfectly, since many which are toxic to the insect species to be controlled have too high a mammalian toxicity to be considered for direct application to food for human consumption.

Malathion has been shown to give good control of Dermestes spp. and subsequent protection, but the minimum effective treatment rate left undesirably high residues of insecticide on the fish (Green, 1967; Proctor, 1972). The potential of fenitrothion and iodofenphos was demonstrated by trials in The Gambia (Conway, personal communication). Further investigations are needed on these and other potentially useful insecticides.

A number of insecticides have recently been evaluated by exposing larvae of D. maculatus on treated filter papers. Fenitrothion, etrimphos, methacriphos, iodofenphos, pirimiphos-methyl and the synthetic pyrethroid permethrin have been tested in this way and found to be effective against the more tolerant larval stage of the insect (Lloyd, personal communication). Further evaluation of these insecticides is necessary using infested dried fish, and a programme of work to do this has started at the Tropical Stored Products Centre.
To date the only insecticides that have been introduced with some success for dried fish protection are based on pyrethrins synergized by piperonyl butoxide. McLellan (1964) found that by dipping properly dried fish in a water emulsion containing 0.018% w/v pyrethrins and 0.036% w/v piperonyl butoxide, good control of Dermestes was obtained. If the dipped fish were well drained they did not become too moist and were acceptable to consumers. Proctor (1972) found this to be the best of several treatments tried and also demonstrated that its employment by fish traders resulted in net profit increases of up to 90%. The problem of keeping residues within limits is the main difficulty associated with the direct treatment of fish with insecticides. Guillon (1976) tested the effectiveness of bioresmethrin (a synthetic pyrethroid) and tetrachlorvinphos for the control of Dermestes maculatus attacking dried fish in Mali. Bioresmethrin was found to be ineffective but tetrachlorvinphos considerably more successful. Fish dipped in a solution of 5g of 75% tetrachlorvinphos wettable powder in 10 ℓ water, showed losses over a 90-day period below 20%. By doubling the concentration of this insecticide solution

losses of treated dried fish were maintained below 10%. Average losses of dried fish due to insect infestation in Mali were quoted to be 40% or more during a 90-day storage period.

Tetrachlorvinphos, also known as Gardona, is of low mammalian toxicity, the maximum residue limit permitted by many government authorities in raw cereals being 10mg/kg. Guillon (1976) recorded residues of tetrachlorvinphos below 10mg/kg 11 days after treatment, these levels falling considerably during the storage period. He concludes that this insecticide, on the basis of the trials conducted in Mali, is effective in controlling D. maculatus infesting dried fish and without hazard to the consumer, especially as this food plays a very small part in the diet.

Animal skins and hides, dried meat, bone and bone meal are readily infestible by Dermestes spp. Storage and transport previously used for these commodities should not be used for dried fish if this can be avoided. If this is not possible, all surfaces should be treated with a residual contact insecticide before storage and transport of dried fish is undertaken. The use of a spray treatment to all exposed surfaces is recommended, e.g. using fenitrothion or pirimiphos methyl applied at 500 mg/m^2. A typical spray treatment to walls, floors and ceilings would require 5 litres of 1% insecticide solution per $100m^2$ to produce this deposit. Sacks containing dried fish may also be treated with an insecticide to prevent cross infestation or reinfestation by insect pests. Treatment of sack surfaces can lead to high residues of insecticides in the contents. Recent spraying trials at the Tropical Stored Products Centre (unpublished data) have shown that the synthetic pyrethroid permethrin is more strongly bound to sack surfaces than are some organophosphorus compounds and permethrin is therefore much less likely to result in high insecticide residues in the sack contents. Further investigations on the insecticidal treatment are necessary but it might prove suitable for use on sacks containing dried fish.

Further advantages of permethrin over natural pyrethrins are its higher photostability and its lower mammalian toxicity.

Kordyl (1976) points out that the recommended means of chemical control of infestation in dried fish which can be applied on a commercial scale and which are without health hazard to the consumer are still awaited. He also comments that this is extremely important on the African continent where different insecticides are handled carelessly causing heavy pollution of rivers and lakes. There is little or no more recent data which will permit the introduction of new or modified methods of loss reduction in dried fish caused by insect infestation. With the present state of technology fumigation might be the most effective means of controlling insect pests in dried fish. An effective fumigation could stop further damage immediately which is unlikely with any other chemical control method except dipping in an insecticide solution. The use of a contact insecticidal spray or a physical barrier to prevent post-fumigation reinfestation is necessary however. The use of a spray treatment alone is unlikely to achieve the necessary penetration to give good control of insect-infested dried fish. D. maculatus was prevented from re-infestating dried hides and skins in The Gambia where spraying was introduced as a replacement for dipping (Taylor, 1977, unpublished data). Spraying might therefore best be considered a means of preventing reinfestation or cross-infestation of dried fish. Dipping techniques might be considered the most feasible means of controlling insect pests in dried fish for the individual producer at the rural level.

Pesticide residues

These have been briefly referred to previously. There is little international uniformity of agreement on pesticide residues, many countries having their own local regulations.

The FAO/WHO Joint Committee on Pesticide Residues (JMPR) makes recommendations with regard to pesticide residues but does not demand any international compliance. However these recommendations are widely accepted internationally since they arise from a scientific appraisal of pesticide usage, food consumption and toxicological data derived from animal feeding trials. For food commodities moving in international trade, member countries of the Codex Alimentarius Commission (sponsored by FAO and WHO) are expected to follow the regulations on pesticide residues made by the Codex Committee.

The only insecticides presently included in the JMPR lists and which are specifically recommended for dried fish protection are pyrethrins and piperonyl butoxide. No guidance is available for other insecticides, and individual countries must adopt their own maximum residue limits from the published data where available, and which is used by other countries such as those in the European Economic Community and also by the United States of America. No residue data is yet available for some of the newer insecticides but the JMPR maximum residue limits in raw cereal grains for the more well established insecticides including fenitrothion and pirimiphos methyl is 10 mg/kg. The residue limits of 3 mg/kg for pyrethrins and 20 mg/kg for piperonyl butoxide laid down for dried fish are similar to those permitted in raw cereal grains. It might be possible as a temporary measure, when considering other potential insecticides for use on dried fish, to adopt the residue limits permitted in raw grains pending the establishment of more specific residue data.

<u>Summary of recommended control measures</u>

1. Wherever fish are processed, stored or marketed:

   (a) Keep the premises, and surrounding area, clean by daily removal (preferably destruction) of fish residues and liberal use of water to wash working areas and equipment.

   (b) Treat drains and soak-aways in the vicinity regularly with disinfectant to destroy bacteria and discourage flies.

(c) Use fly-proof screens and self-closing doors to prevent flies gaining access to fish.

(d) Hang up sticky fly-traps or, if practical, install insect electrocutors.

(e) Prevent the development of indigenous pest populations by regularly spraying internal surfaces of buildings or space fogging with contact insecticide (outside normal working hours and ensuring that stocks of fish are covered to avoid contamination).

(f) If possible, construct the floor of smooth-capped concrete (also under drying racks) to facilitate cleaning and eliminate an important breeding ground for flies.

2. Ensure that vehicles used for transporting fish are clean and free from infested residues before use and clean them after use. Regular fish transporters could be fitted with (detachable) fly-proof screens and self-closing doors; they should be sprayed internally with contact insecticide at regular intervals.

3. Containers, (boxes, sacks etc) for the transportation and storage of fish, should be cleaned and disinfested before use. Sizable concerns could equip themselves with facilities for cleaning and fumigating containers but small-scale traders are unlikely to be able to do this. Municipal or Central Government Authorities may be able to help here by installing the required equipment in or near important fish markets and charging a nominal fee for container disinfection. Polyethylene (or other plastic) bags should be used in situations where their practicality has been demonstrated, providing the precautions associated with their use can be observed.

4. Improved smoke drying and brining techniques minimize the risks of insect infestation and bacterial contamination; they should be employed whever the product has a ready market. In the absence of such a market, serious consideration should be given to mounting campaigns to gain their acceptance by consumers.

5. The use of fumigants and persistent insecticides to control or prevent insect infestations in dried fish.

<u>The effectiveness of currently recommended control measures and indications for further research work.</u>

General hygiene, smoking and brining assist in reducing insect infestation in dried fish and should continue to be recommended as part of control measures adopted.

At present only two insecticides, pyrethrins and tetrachlorvinphos, have been seriously recommended for uses as a dipping treatment. Pyrethrins have been used effectively for a number of years to protect dried fish against insect pest damage and despite the lack of residue data should at present be regarded as the principal chemical control method to be recommended where dipping is employed. Tetrachlorvinphos has no internationally accepted residue tolerance levels and where export of dried fish is involved, use of this insecticide must be questionable.

There is a clear need for further research into residue levels attained in dried fish after treatment with pyrethrins or tetrachlorvinphos. Residue levels will vary with the species of fish under investigation and research programmes should be designed to include this factor.

Laboratory and field trials are neccessary in order to evaluate the effectiveness of newer persistent insecticides in controlling <u>Dermestes</u> spp. Some synthetic pyrethroids have potential as dried fish protectants and should be included in research programmes. All investigational research should include the collection of chemical residue data in treated fish.

It has been established that methyl bromide can be used to control insect pests attacking dried fish and at centres where considerable quantities are handled Dermestes populations in the surrounding area may cause infestation pressure to be high. In such centres rapid fumigation with methyl bromide is justified and large brick and masonry chambers for this purpose should be locally constructed. Where small quantities of fish are handled, purpose-built steel chambers of the type used at port quarantine stations are recommended. Little is known about the effectiveness of phosphine as a fumigant for the treatment of dried fish to control Dermestes spp. There is a need, therefore, to establish both the basic data about its effectivenss, and to investigate methods which could be adopted for insect control in the field. The basic disadvantage with phosphine might be the longer treatment time in comparison with methyl gromide as a fumigant. However phosphine has found such diverse uses in fumigation of grain and other products that it must be well worth while considering its use for dried fish protection. Phosphine is relatively cheap and widely available, its simplicity in use could outweigh the disadvantages of a longer exposure time.

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