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THE EFFECTS OF SALT TREATMENT OF FISH ON THE DEVELOPMENTAL BIOLOGY OF *DERMESTES MACULATUS* (COLEOPTERA, DERMESTIDAE) AND *NECROBIA RUFIPES* (CLERIDAE)

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Fish meal containing various levels of common salt concentration from 3.18% to 10.20% was used to investigate the effects of salt on the developmental biology of *D. maculatus* and *Necrobia rufipes*. Larval development in both beetles was prolonged in salted fish and larval mortality was total in *D. maculatus* at salt concentrations of 9.20% and 10.20%. Salting caused decreased larval and adult body weight, reduced fecundity and egg viability. The results are discussed in relation to fish processing in Nigeria.

Previous workers (Taylor, 1964; Toye, 1970; Osuji, 1974a) have emphasised the importance of *Dermestes maculatus* Deg. and *Necrobia rufipes* Deg. as pests of dried fish in Nigeria. Osuji (1975a and b) has also shown that there is a close correlation between the traditional methods adopted in fish processing, handling and marketing in that country and the initiation and growth of beetle infestation in dried fish. The lack of standardisation and control in the dried fish industry there is largely accountable for the enormous qualitative and quantitative losses incurred at all stages from the landing of fish to its marketing. In the Lake Chad district, fishermen sometimes apply unmeasured quantities of common salt (sodium chloride) to fish flesh before sun drying it. Even such large concentrations of salt (found on analysis to be more than 40 % by weight) do not give adequate protection against insect damage, since salting is not normally accompanied by other measures which would reduce infestation. Moreover, the heavily salted fish is not highly priced in Nigerian markets.

Amos (1968) described laboratory observations on the effects of salt treatment of sea-fish on the development of *D. frischii* Kug. while Mushi & Chiang (1974) carried out similar investigations using *D. maculatus* on fresh water fish. In both instances, the development of the beetles was inhibited by high salt contents, some of them up to 60 % by weight. There is no record of previous investigation on the effect of salt treatment on *N. rufipes* in dried fish. The present paper describes investigations into the effects of the addition of comparatively low concentrations of salt to dried fish on the development of larvae of *D. maculatus* and *N. rufipes* in it.

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MATERIALS AND METHODS

Salt treatments of fish. The fish specimens used were obtained from a mixture of "Chisawasawa" and "Utaka" which are shoaling species from Lake Malawi and supplied by the Tropical Products Institute laboratories in London. They were treated as follows:

1. 1 kg of whole fish dried in a laboratory kiln at 30° C for 48 hr and then at 40° for 4 days. These fish had no salt treatment, and served as control.
2. 1 kg of whole fish surrounded with granular salt for 6½ hr and then dried as in 1.
3. 1 kg of whole fish immersed in 75 % brine[1]) for 30 min and then dried as in 1.
4. 870 g of whole fish immersed in 75 % brine for 60 min and then dried as in 1.
5. 1 kg of whole fish immersed in 75 % brine for 90 min and dried as in 1.
6. 1 kg of whole fish immersed in 75% brine for 120 min and dried as in 1.

In all cases the resulting dried fish was minced and each type of fishmeal was kept in a large open storage jar (21 cm deep and 9 cm wide) in one of the two controlled environment rooms (see later) for 4 days to equilibrate with the experimental conditions. The moisture content of each preparation was determined after the stabilisation period and at the end of the experiment, by the oven method described fully elsewhere (Osuji, 1974b). Dried fish lipid content was determined by total solvent extraction in chloroform-methanol (Osuji, 1974c). "Quantab" chloride titrators (Ames Company, Indiana, U.S.A.) were used to estimate the sodium chloride content of each fish preparation.

Cultures of *D. maculatus* and *N. rufipes*, in fish meal, cheese and bacon, were supplied by the Tropical Stored Products Centre, Slough, England. Individuals of each beetle were isolated at the pupal stage, and pairs of the newly emerged adults were kept separately in specimen jars (6.5 cm deep and 6.5 cm wide). The experiments were performed in two controlled environment rooms 30° and 75-80 % R.H. and 28°, 75-80 % R.H.

Studies on D. maculatus. Eggs of *D. maculatus* were readily isolated for incubation at 30°, 75-80 % R.H. by inserting folded pieces of black paper into the jars containing mated females. Larvae were removed by means of a paint brush on the day of hatching, into specimen tubes (7.5 cm, 2.2 cm wide) containing the various fish preparations. Forty larvae were bred on each food in each of the two constant temperature rooms. The fish meal in each tube was replenished every week from the appropriate reserve kept in the same room. Larval moults were recorded at each food change.

To ascertain the effect of the salted fish on the body weights of the larvae, ten larvae from each lot were weighed separately every 5 days in gelatin capsules on a Cahn electro-balance. The duration of development (hatching to emergence) was also recorded in each case. Adults were weighed on emergence as for the larvae.

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[1]) The term "75% brine" means *brine of 75% saturation.*

Pairs of these first generation adults were subsequently placed separately in the specimen jars previously described. The fecundity of each female was estimated by totalling its daily oviposition. As the females tended to oviposit preferentially in folded pieces of black paper when ground fish was provided, the counting of eggs was greatly facilitated. However, it was still necessary to search through the fish meal for any eggs laid there. The number of larvae that hatched from the eggs laid by each female was also recorded.

Studies on N. rufipes. It was only possible in the time available to investigate the effect of the various salt treatments of fish on the development of *N. rufipes* at 30° and 75-80 % R.H. Eggs were obtained from isolated pairs as for *D. maculatus* above. Forty larvae were bred on each of the fish preparations 1-4. Emergent adults were weighed as for *D. maculatus.*

OBSERVATIONS AND RESULTS

Table I gives the salt, moisture and lipid contents of the dried fish preparations. The treatments 2-4 produced dried fish of comparable salt contents, with the dry salting (Kenching) giving a slightly higher salt concentration than the others. The

TABLE I

Salt, moisture and lipid contents of dried fish specimens

	salt %	moisture %	lipid %
1. unsalted fish	0.4	13.7 (13.6—13.7)	31.4
2. dry salted 6½ hr	3.8	10.5 (9.5—11.4)	30.2
3. brined ½ hr	3.2	13.0 (12.3—13.7)	34.2
4. brined 1 hr	3.5	9.9 (9.8—10.1)	31.0
5. brined 1½ hr	9.2	6.2 (6.1— 6.3)	19.7
6. brined 2 hr	10.2	6.6 (6.5— 6.7)	23.9

highest salt concentration obtained was 10.20 % in 6. Better dehydration of fish was achieved with increasing salt content, as reflected in the significantly low moisture contents in 4-6. The fish were of rather high lipid content, a factor that would normally favour the development and abundance of both *D. maculatus* and *N. rufipes.* The sample without salt treatment showed considerable deterioration after a few days of storage while all the salted ones remained in good condition for over 5 months.

Fig. 1 shows the body weights of larvae *D. maculatus* fed on the different fish specimens at 30°, 75-80 % R.H. The weight of the last-instar larva in the control was much greater than any of the others. The larval weights in 5 and 6 stayed low since the individuals remained in the first or second instars even after development had been completed in 1. Larval mortality was high in samples 2-6, mortality was greater at higher salt concentration; in 5 and 6, it was total. At both 30° and 28°, larval development was completed in samples 1-4, but it was greatly prolonged in the salted samples (Table II). On average, there were six larval moults in each of

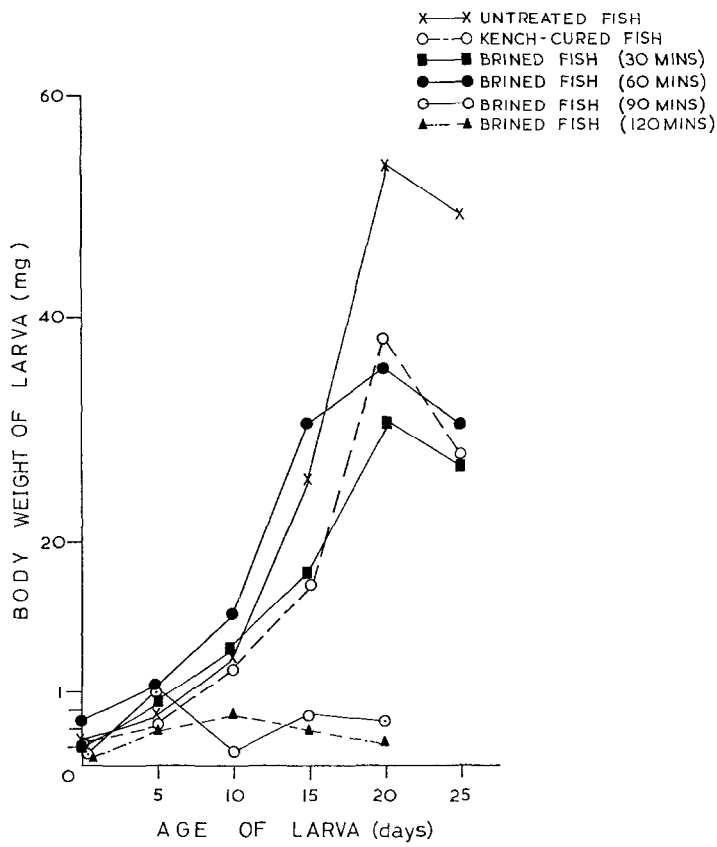

Fig. 1. Body weights of larvae of *D. maculatus* fed on the various specimens of fish meal at 30°, 75—80% RH.

the salted samples and five in the control. The faeces of larvae fed on salted fish were in the form of long sticky threads adhering to their anal openings as different from the dry pellets normally excreted by the beetles.

The adults which emerged from the salted samples were generally lighter in weight than those of the control (Tables IIb and IIIb). The rates of oviposition by females fed on the various fish samples at 30°, 75-80 % R.H. are plotted in Fig. 2. A pre-oviposition period of 3-4 days was observed in the salted samples and only one day in the unsalted fish. Oviposition was irregular in all the individuals fed on the salted samples and the total egg output was low in each case (Table IV). Many of such eggs were unviable and were usually shrivelled soon after they were laid. The incubation period of the eggs was 3 or 4 days in the salted fish and not more than one day in the control.

The developmental periods and mean body weights of females recorded for *N. rufipes* in the various samples are shown in Table V. Larval development was

TABLE II

(a) *Development of* D. maculatus *in salted dried fish at 30° and 75—80% R.H.*

Fish sample	Pre-oviposition period (days)	Incubation period (days)	Larval developmental period (days)		Total developmental period (days)		Number of moults
			Mean	S.D.	Mean	S.D.	
1	1	2	21.5	1.5	29.2	2.7	5
2	3	3	29.5	1.0	38.5	2.5	6
3	3	4	30.2	1.5	39.2	3.2	6
4	3—4	3	36.8	1.9	47.3	3.0	6
5	3—4	4	—		—		—
6	3—4	4	—		—		—

(b) *Body weights of adults of* D. maculatus *on emergence*

	Males		Females	
	Mean weight (mg)	S.D.	Mean weight (mg)	S.D.
1	33.1	1.3	44.5	1.1
2	26.7	1.0	38.1	1.5
3	25.9	0.1	32.9	0.2
4	22.3	1.5	33.4	0.2

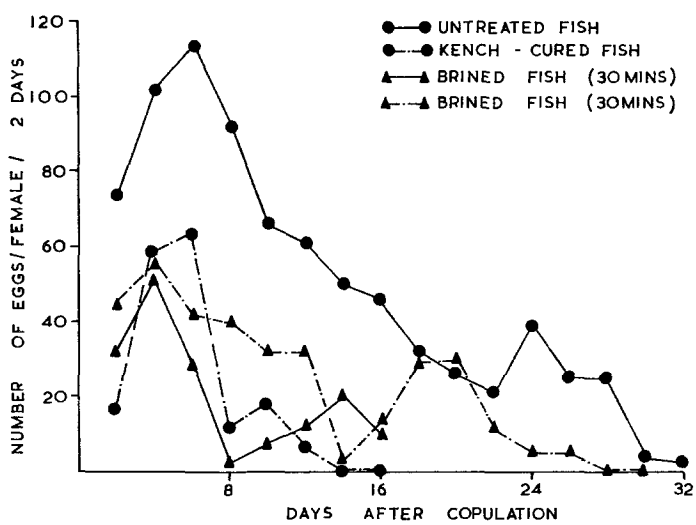

Fig. 2. Oviposition rates of females of *D. maculatus* in various specimens of fish meal at 30°, 75—80% RH.

TABLE III

(a) *Development of* D. maculatus *at 28° and 75—80% R.H.*

Fish preparation*	Larval developmental period (days)		Total developmental period (days)		Number of moults
	Mean	S.D.	Mean	S.D.	
1	29.0	1.0	39.5	2.0	6
2	36.3	2.0	50.0	2.3	6
3	36.5	3.0	50.5	2.0	6
4	40.3	2.0	56.3	3.1	7
5	—		—		
6	—		—		

(b) *Body weights of emergent adults of* D. maculatus *at 28° and 75—80% R.H.*

	Males		Females	
	Mean weight (mg)	S.D.	Mean weight (mg)	S.D.
1	35.2	1.4	45.8	1.9
2	29.0	1.4	36.2	1.0
3	23.1	1.2	33.5	1.4
4	26.6	1.8	27.1	2.1

* See text and Table I.

TABLE IV

Fecundity of females of D. maculatus *at 30°, 75—80% R.H.*

Fish preparation	Mean number of eggs/ female	Mean % of eggs hatching
1	784	98.2
2	164	73.8
3	175	55.6
4	291	69.1

TABLE V

Development of Necrobia rufipes *in salted dried fish at 30° and 75—80% R.H.*

Fish preparation	Larval developmental period (days)		Total developmental period (days)		Mean weight of (female) adults on emergence (mg)
	Mean	S.D.	Mean	S.D.	
1	42.0	2.5	52.2	2.0	4.5
2	71.5	3.8	83.0	3.9	5.0
3	71.0	2.2	85.0	2.1	3.9
4	85.0	2.8	98.0	3.9	4.9

significantly prolonged in all the salted samples, more so than for *D. maculatus*. The body weights in this case, however, showed no definite correlation with the food.

DISCUSSION

The data presented above provide experimental evidence favouring the view that proper salt treatment of fish can be effective in reducing the infestation of the dried product by *D. maculatus* and *N. rufipes*. With respect to *D. maculatus*, salting seemed to increase the pre-oviposition period and reduce fecundity besides prolonging the larval developmental period and causing high larval mortality. These factors would reduce the overall capacity for increase in abundance by the beetle.

Since salt concentrations of 9-10 % accompanied by thorough dehydration (to about 6 % moisture content) effectively inhibited the development of *D. maculatus*, heavy salting as is often practised in fish curing in Nigeria is hardly necessary, especially as the product is usually devalued in consequence. Besides, other forms of biodeterioration were effectively prevented by the lower salt concentrations used in the present investigation. Traditional methods adopted in fish processing are suitable for proper dehydration of fish. A combination of regulated salting and thorough drying may, therefore, be recommended for wider application in the industry to reduce beetle damage to dried fish.

Some indication is obtained from the appearance of the larval faeces as to a possible mode of action of common salt on *D. maculatus*. It is likely that increased sodium chloride in the diet interferes with the metabolism of the beetles thus upsetting the general capacity of the Malpighian tubules to cope effectively with excretory products. Other unpublished observations by the author lend support to this suggestion of excretory malfunction.

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ZUSAMMENFASSUNG

DIE WIRKUNG EINER SALZBEHANDLUNG VON FISCHEN AUF DIE ENTWICKLUNGSBIOLOGIE VON DERMESTES MACULATUS *UND* NECROBIA RUFIPES

Fischmehl mit verschiedenen Konzentrationen von Kochsalz (3,18 bis 10,20%) wurde verwendet, um die Wirkung einer Salzbehandlung auf die Entwicklung von zwei Schädlingen an Trockenfischen in Nigeria zu untersuchen. Bei beiden Käfern war die Larvalentwicklung in Salzfischen verlängert, bei *N. rufipes* bis zum doppelten. Larvale Sterblichkeit war hoch oder 100% bei Salzkonzentrationen von 9,2 bis 10,2%; Körpergewicht von Larven und Adulten, Fruchtbarkeit und Lebensfähigkeit der Eier waren reduziert. Salz unterstützte Konservierung und Dehydrierung des Fisches. Die Ergebnisse zeigen, dass mässige Salzkonzentrationen, kombiniert mit vollständiger Trocknung, einen guten Schutz vor Käferbefall abgeben.

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