POST-HARVEST MANAGEMENT AND SPOILAGE OF TROPICAL SHRIMPS (*Penaeus notialis*)

by

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Abstract

Traditional shrimp processing sites and marketing centres were surveyed to evaluate the effectiveness of traditional methods of processing and storage. Smoking and sun-drying were found to be the only methods used in shrimp processing in Ghana. The most common marine shrimp species, *Penaeus notialis,* was smoked in traditional ovens using mainly *Paspalum vaginatum, Aristida sp.* and *Philoxerus vermicularis* plants which impart an orange glossy colour to the smoked shrimps. Drying involved spreading the shrimps in the open sun on mats, sea sand or bare ground. Improper and unhygienic management (including personal body cleanliness, unclean equipment and environment), handling, storage and marketing procedures were found to lead to massive economic and financial loss to the processors and retailers alike as a result of high levels of contamination of the shrimps. A beetle, *Dermestes frischii* and its larvae were found to infest the shrimps in large numbers resulting in considerable quantitative and qualitative losses. Packaging is done by loading the fish in sacks and paper-lined baskets in large quantities such that stacking during transportation leads to fragmentation and spoilage. Micro-organisms isolated in processed shrimps include *Enterobacter, Aeromonas, Pseudomonas, Acinetobacter, Micrococcus, Corynebacterium, Bacillus, Monilia, Aspergillus* and *Mucor.* However, no pathogen of public health significance was isolated. Quantitative aerobic bacterial load recorded for fresh shrimps was high ($2.4x10^8$ bact/g). For the sundried and smoked marine samples, counts were comparatively low. Smoked lagoon samples recorded $7.8x10^4$ org/g. Negligible levels of mould and yeast counts were recorded especially for the smoked marine shrimps (<10 cfu/g) while sun-dried marine and smoked lagoon shrimps recorded $1.4x10^1$ and $1.8x10^1$ cfu/g respectively. With storage, bacterial count increased to between $8.7x10^3$ and $2.4x10^5$ org/g for market samples as compared to negligible increase in values of samples stored in the laboratory over 4 month period. Mould count for market samples also increased to between $2.3x10^1$ and $4.6x10^3$ cfu/g over the same period. Increase in microbial count correlated with decrease in sensory quality. Moisture content of marine smoked and sun-dried shrimps ranged from 14-18%, protein 50-58.7%, fat 2.4-4.1%, free fatty acid (FFA) content 22-43% (as oleic), with sun-dried samples having higher FFA content than smoked samples. Smoked lagoon shrimps from markets had moisture content of 14%, protein 68%, fat 3%, FFA 22% (as oleic) while those from processing sites had moisture 17.6%, protein 57.6% and fat 4.6%. The process of sun-drying exposed shrimps more to deterioration due to oxidation, with resultant increase in FFA than the smoking process.

1. INTRODUCTION

In Ghana, the most important shrimp species of commercial importance harvested are *Penaeus notialis* and *Parapenaeopsis atlantica.* Artisanal fisherfolk employ beach seine-net with a fine mesh to harvest post larvae and juveniles of various sizes. The larger ones are smoked and the smaller sized ones are sun-dried.

Processing of shrimps are carried out in two ways, namely by smoking or sun-drying. These processes impart characteristic flavour to the shrimps which are used either as whole meals or condiments in Ghanaian dishes. However, due to temperature abuse and poor management of the shrimps from harvest through storage, unacceptably high and serious economic losses as well as public health consequences have been recorded.

Traditional processing, handling, storage and packaging of shrimps continue to be in the crude stages where unconventional methods are employed for both the storage and retail markets. Effective monitoring, evaluation and standardisation of these activities with the view to improving reduction in huge losses due to various lapses in handling/processing including insect infestation has been lacking. Structures employed to process and store shrimps have not been evaluated with the view to improvement upon the old existing ones in use.

In Ghana, fresh shrimps landed offshore are generally not deheaded. Carroll et. al. (1968) observed that removal of the heads reduced bacterial load on the shrimp by 50-80%. However, deheading exposes the shrimps tail muscle to bacteria organisms from its own digestive system, the hands of the handlers, the knife surface and all contact surfaces including the containers into which the shrimps are kept. Bieler et. al. (1973) also showed that there was a lower total bacterial counts, higher solids contents were maintained and the organoleptic acceptability was more favourable for whole than deheaded shrimps.

Bacterial numbers in shrimps immediately after capture are very low (Kartintsev, 1981), but after death there occurs reduction in quality due to deterioration as a result of microbial and biochemical changes. Biochemical changes include autolysis which cause unpleasant odour, drip, colour and textural changes. Rigor mortis causes the shrimps to become non-transparent, beginning with the darkening of the cephalothorax as a result of concentration of complex of proteases there; and the tail becomes arched in a characteristic way while the colour of the shrimps darken. At this stage, fluid begins to drip from the shrimp. The darkening of the cephalothorax is believed to be caused by catechol oxidase (Oshima and Nagayama, 1980). Continued storage of the shrimps results in flaccidity of the body tissues, leading on to subsequent bacterial decomposition of the tissue. Hence sensory investigations of general quality include taste, colour and texture.

On shelf life studies of shrimps (*Penaeus merguiensis)* stored at different temperatures ranging from 0°C to 35°C, Shamshad et al. (1990) studied the sensory, microbiological and biochemical changes. They recorded a mean aerobic plate count of fresh shrimp initially

$5.0x10^5$ cfu/g which increased with time to $6.4x10^9$ cfu/g after 24h., when stored at a temperature of 35°C. The increase was found to be more rapid at higher temperatures and correlated with the rapid decrease in sensory quality (odour, colour, texture) of the shrimp with an increase in trimethylamine (TMA), total volatile bases (TVB), pH and indole with respect to time and temperature. Shelf life of the shrimps was found to range from 7h. at 35°C to 13 days at 0°C.

Several studies have been carried out on the microbiological and biochemical changes occurring in fresh shrimps during storage and commercial handling (Walker et al., 1970; Cobb et al., 1973 and 1977; Cann, 1977; Matches, 1982; Krishnamurthy and Karunasagar, 1986; Zuberi et al., 1987). It was observed that ice storage of shrimp was not always done properly, particularly in developing countries.

Marine shrimps from warm waters of tropical countries carry a microbial population dominated by Gram-positive bacteria such as *Micrococcus,* coryneforms and *Bacillus* (Liston, 1980). Quantitatively total aerobic counts are of the order of 10^6/g when captured, whereas a range of 10^2-10^3/g is common for cold-water species (Zapatka and Bartolomeo, 1973) for predominantly Gram-negative microbes including *Moraxella, Acinetobacter, Pseudomonas, Flavobacterium* and *Vibrio* (Cann, 1977).

An important problem in cured shrimp management is insect infestation. Processors have resorted to the use of household insecticides application or dyes in order to reduce infestation during processing and storage.

Shrimp processing industries that have sprung up in towns where fishing activities are carried out lack logistics as to proper management of the commodity and attainment of safe standards in processing to curtail spoilage.

Currently there is increasing consumer concern about the safety of seafood such as shrimps due to the nature and level of unsatisfactory handling procedures during processing, storage and marketing.

To ensure plentiful, high quality, but above all, safe food supply is of great concern in the food industry, hence the need to investigate stored, processed shrimps cannot be over-emphasised. In this study, therefore, the processing and storage techniques used in the shrimp industry was investigated and related to the microbiological, nutritional and sensory characteristics of the stored products.

2. MATERIALS AND METHODS

2.1 Survey of shrimp landing and processing centres

A survey of major shrimp (*Penaeus notialis)* landing and processing sites was carried out by means of a questionnaire which served as a means to obtain information to identify major processing areas from which sampling was carried out for physico-chemical, microbiological and sensory analysis. Highlighted in the survey were the traditional processing ovens and equipment used; handling, smoking, drying and packaging methods; shrimp storage structures and methods of transportation of shrimps to marketing centres.

2.2 Storage trials

Two batches of samples for each shrimp type (smoked and sun-dried marine shrimps; and smoked lagoon shrimps) were obtained. One set labelled Day 0 storage time was analysed in the laboratory on the day of purchase from the processing site to obtain its quality characteristics. The other set was stored for 4 months under market and laboratory conditions to investigate the storage stability and shelf life of the shrimps. After the 4 months period, representative samples of the stored shrimps were then analysed for their physical, chemical, sensory and microbiological characteristics to obtain quality indices of the samples after storage.

2.3 Quality evaluation

Microbiological analyses

From all samples 10g were homogenised in 90ml. Saline Peptone solution by use of a stomacher (Lab Blender, Model 4001, Seward Medical, London, England) for 30 s. Serial dilutions of 10^{-1} - 10^{-6} were prepared and 1ml. was pipetted into Plate Count Agar and incubated at 30°C for 72 h. From appropriate ten-fold dilutions, pour plate countings were carried out using Malt Extract Agar with incubation at 25°C for 5 days for identification of mould and yeast organisms. Coliform organisms were investigated by pipetting 1ml. of 10^{-1} and 10^{-2} dilutions of the shrimp suspension into sterile petri dishes where Tryptone Soya Agar was added (Anon, 1992). For determination of *Staphylococcus* sp., 5g sample shrimp powder was placed in cooked meat medium; then 0.1ml of the undiluted stock solution was transferred to Baird-Parker's medium. The inoculum was evenly distributed and incubated at 37°C for 24-48h. *Vibrio parahaemolyticus* was determined as per Anon, 1982. Streaks of incubated appropriate dilutions were made onto Thiosulfate-citrate-bile salts-sucrose (TCBS) agar; after which biochemical verification tests were carried out. *Salmonella* bacteria were identified by the method of Anon, 1991. Four separate procedures were carried out involving pre-enrichment in buffered peptone water, selective enrichment in Rappaport-Vassiliadis broth, plating out in Xylose-lysin-deoxycholate agar and confirmation by subculturing and biochemical tests. Gram stained reactions of bacteria types were identified.

Physico-chemical analyses

Average weight of each shrimp type was determined on lot sizes of 100 shrimps while the average size was determined by measuring shrimp length and thickness using a pearl chrome-plated micrometer (Moore and Wright, Sheffield Ltd., England). Proximate composition of samples was determined by standard methods (AOAC, 1984). Free fatty acids content of the samples was determined using the chloroform/methanol extraction technique described by Bligh and Dyer (1959).

Sensory evaluation

A quantitative descriptive sensory analysis was employed. This involved evaluation of colour, flavour, aroma and chewiness of the shrimps by expert panellists (Plahar et al., 1991). For each sample, an unstructured score card with sensory descriptions at each end of a 10cm long line was used to make marks in relation to the description of the attribute (Johnson et al., 1988). The distance of the tail end of

the line to the mark was used as the numerical score. For each attribute, the mean score was obtained from several scores. Statistical significance of observed differences among means was evaluated by analysis of variance (ANOVA), and the least significant difference test (LSD) was used for comparison of the means (Steel and Torrie, 1980).

2.4 Colour development of shrimps during smoking

Three plants observed to be used in colouring shrimps during smoking process were investigated for their active principles. Ethyl alcohol extracts of the plants, namely *Aristida sp., Paspalum vaginatum* and *Philoxerus vermicularis* were made and the alcohol evaporated under vacuum to avoid loss of volatile compounds. The residue was further extracted to separate two main groups of compounds, the acid/neutral organic compounds and the basic organic compounds (including alkaloids) using appropriate solvents. The extracts were then subjected to Thin Layer Chromatography (TLC).

2.5 Identification of insect and larvae

Adults and larvae of insects were collected from the 4 months stored smoked and dried shrimps under market conditions. The adults were identified by use of a low-power microscope and an identification key (Peacock, 1975) to observe the distinguishing characters. The larvae were distinguished by their hairiness and dark colour.

3. RESULTS AND DISCUSSION

The most widely used traditional processing methods in preserving fresh-water and marine shrimps were sun-drying and smoking. Freshwater shrimps looked more attractive in appearance, contained less debris and sand. During processing, three plants, namely *Aristida sp., Paspalum vaginatum* and *Philoxerus vermicularis* were used singly or in combination to impart a bright light orange to brown glossy colour to the shrimps (*P. notialis)*, by placing them in stoke holes of traditional ovens and igniting to generate smoke.

The active components common to these plants which may be responsible for the attractive colour development in the shrimps were observed to contain a compound that was detected as a dark spot under Ultra Violet (UV) light and also reacted with Iodoplatinate spray reagent to produce a yellow spot (Rf 0.87) with methanol: ammonia (100:1.5) as developing solvent.

Packaging and storage techniques were found to be inadequate in avoiding infestation of the stored products by a beetle, *Dermestes frischii* and its larvae, which were found to cause considerable quantitative and qualitative economic loss in the form of fragmentation. On a smaller scale, ants were found to cause some damage as well. Fragmentation of the cured shrimps was found to destroy the wholesomeness of the shrimps rendering it into a powdery and unattractive mass easily invaded by opportunistic micro-organisms.

Quality loss was also caused by the presence of insect bodies and cast skins of larvae as well as their droppings. The extent and value of quantitative losses caused to dried fish by *Dermestes spp.* have been assessed by various investigators (Osuji, 1975; Peacock, 1975 and Coombs, 1981) with estimates ranging from negligible up to 50% weight loss, depending on length of storage, salt content, moisture content, climatic conditions and general hygiene during processing and storage.

Initial infestation of the shrimps may have been due to invasion by flying adult beetles which may have laid their eggs on the dried shrimps, this being enhanced by the unavailability of fly-screens around and over drying racks. The use of clean good-quality sacks during storage and packaging to the marketing centres was non-existent, as this practice may have drastically slowed down rates of immigration or even reduced the *Dermestes* infestation pressure on the shrimps.

Osuji (1975) observed that cross-infestation by *Dermestes spp.* was reduced when jute sacks were lined with polyethylene and thick brown paper. During this study, it was observed that sacks and paper used were dirty and torn to expose the shrimps for easier access to flying adults and crawling *Dermestes* larvae. No polyethylene bags were used to serve as a barrier. The sacks and paper were reused several times oven without adequate cleaning; so that infestation was found to be initiated by the larvae, adults or even their eggs present in fish residues left on the sacks or paper, or by adults emerging from pupation chambers in wooden structures. In the laboratory storage trials carried out, it was observed that where the stored products have been initially infested, the use of polyethylene bags did not protect the shrimps any further, as the adult *Dermestes* were found to eat up and make holes in the polyethylene. Hence as observed, only sound, uninfested shrimps may be protected by this method. The risk of such infestation may be reduced by improved hygiene and by placing the shrimps on raised structures above the ground as well as treating the wooden structures with a recommended insecticides.

D. maculatus and D. frischii are the two commonest species of *Dermestes* that infest cured fish in Ghana with the latter being associated with marine shrimps (Coombs, 1981). The *Dermestes* adults fly and easily disperse to new sources of food and sacks of shrimps under storage due to their large numbers and increased population rate of about 30 times per month (Howe, 1953). The adults were found to feed on the shrimps while the larvae burrow into the flesh as they feed and as they moult, leave their cast larval skins which look unsightly.

On the market stored shrimps these activities of *D. frischii* was found to reduce a portion (about 5%) of the stored products to powder and hollow shrimp structures, the inside of which had been eaten out over the storage period.

Economic loss over a longer period of storage would have been enormous considering the number of *D. frischii* observed; thus shorter periods of storage with intermittent smoking or drying coupled with proper hygiene and handling procedures would help to alleviate the rate of infestation.

The initial physical characteristics of processed marine and lagoon shrimps prepared for storage (Table 1) showed the lagoon samples to be largest in size as compared to the marine samples; in addition, all the samples were physically intact with no initial insect or visible mould infestation.

Chemical composition (Table 2) showed an initial moisture content ranging from 14 to 16%, protein 60 to 80%, fat 3.3 to 4.% and free fatty acids 19 to 36% (as oleic). However, the sun dried samples recorded higher FFA content than smoked samples. The process of sun-drying may have exposed the shrimps to more deterioration due to oxidation with the resultant increase in FFA than the smoking process. Poor storage conditions may also be responsible for the increase in FFA values.

Quantitative descriptive sensory analysis of the processed marine and lagoon shrimps (Table 3) showed golden brown colour and glossy appearance for sun-dried samples while smoked marine samples had colour scores close to dark brown with a dull appearance. Aroma-wise, the smoked marine samples were sweet-smelling while the marine samples had lower aroma scores described as neither rancid nor fresh sweet smelling. Similarly, the flavour of sun-dried samples which were between off flavour and typical scored lower than the smoked samples, thus showing some appreciable degree of deterioration in flavour.

The initial microbiological quality of processed shrimps under storage showed low bacterial load of $4.3x10^2$, $5.1x10^3$, $7.8x10^4$ orgs/g for the sun-dried marine, smoked marine and smoked lagoon samples respectively (Table 4). Negligible levels of mould and yeast counts were recorded. While non-faecal coliforms were detected in smoked lagoon shrimps only, no pathogenic micro-organisms like *E. coli, S. aureus* and Salmonella were found. However, other microflora isolated were *Bacillus, Enterobacter, Corynebacterium , Micrococcus, Mucor* and *Monilia sp.*

Table 1. Physical characteristics of processed marine and lagoon shrimps under storage study (0 and 4 months)

Sample	Weight (g/100 shrimps)		Length (cm)		Thickness (cm)	
	Storage time (months)					
	0	4	0	4	0	4
Market storage						
Smoked marine shrimps	89.8	104.6	4.1	3.9	0.22	0.23
Sun-dried marine shrimps	4.8	5.2	2.0	1.9	0.18	0.18
Smoked lagoon shrimps	141.3	240.1	12.1	11.8	0.45	0.55
Laboratory storage						
Smoked marine shrimps	89.8	130.8	4.1	4.0	0.22	0.22
Sun-dried marine shrimps	4.8	5.7	2.0	1.9	0.18	0.18
Smoked lagoon shrimps	141.3	170.1	12.1	12.0	0.45	0.45

Table 2. Chemical composition of freshly processed shrimps under storage study (0 and 4 months)

Sample	Moisture (%)		Protein (%)		Fat (%)		FFA (% oleic)	
	Storage time (months)							
	0	4	0	4	0	4	0	4
Market storage								
Smoked marine shrimps	14.0	17.2	70.2	64.4	3.6	2.9	19.1	26.7
Sun-dried marine shrimps	15.9	18.1	62.4	61.0	3.3	3.0	35.8	34.4
Smoked lagoon shrimps	15.0	19.4	79.5	72.7	4.0	2.7	22.8	24.3
Laboratory storage								
Smoked marine shrimps	14.0	16.8	70.2	64.4	3.6	2.5	19.1	23.7
Sun-dried marine shrimps	15.9	17.2	62.4	61.0	3.3	2.8	35.8	35.9
Smoked lagoon shrimps	15.0	19.0	79.5	72.7	4.0	3.8	22.8	25.1

Table 3. Quantitative descriptive sensory analysis of processed marine and lagoon shrimps under storage study (0 and 4 months)

Sample	Sensory scores [1]									
	Colour		Aroma		Flavour		Chewiness		Appearance	
	Storage time (months)									
	0	4	0	4	0	4	0	4	0	4
Market storage										
Smoked marine shrimps	4.5	3.5	8.2	6.5	7.0	5.5	5.5	4.5	3.0	1.5
Sun-dried marine shrimps	8.5	7.5	7.5	5.0	4.8	2.0	8.0	9.0	7.0	4.5
Smoked lagoon shrimps	6.0	3.0	8.6	6.0	8.0	6.0	5.5	6.5	8.5	3.5
Laboratory storage										
Smoked marine shrimps	4.5	4.0	8.2	7.0	7.0	6.0	5.5	4.5	3.0	2.0
Sun-dried marine shrimps	8.5	8.0	7.5	5.5	4.8	2.5	8.0	9.0	7.0	5.0
Smoked lagoon shrimps	6.0	5.5	8.6	6.5	8.0	6.5	5.5	6.5	8.5	7.5

[1] *Scoring system*

Colour :	*0 = dark brown,*		*10 = golden brown*
Aroma :	*0 = off odour or rancid,*		*10 = fresh sweet smelling*
Flavour :	*0 = off flavour,*		*10 = typical*
Chewiness :	*0 = tender,*	*5 = chewy,*	*10 = tough*
Appearance :	*0 = dull,*		*10 = glossy*

Effect of 4 months storage showed changes in the weight of the shrimps (Table 1) being attributed to the increase in moisture content (Table 2) while physical characteristics as length and thickness values remained constant. More moisture was however absorbed for market stored shrimps than for laboratory stored products (Table 2) over the same period of storage. The shrimps stored in the laboratory were enclosed in polyethylene bags which prevented absorption of water molecules unto the surface of the shrimps. Protein levels decreased by about 5% and may be due to breakdown to volatile components such as ammonia, the odour of which was detected in the stored shrimps. Fat content was found to decrease with significant increases in FFA in stored smoked marine and lagoon samples, whereas the sun-dried shrimps did not show any significant increase over the initial high levels. This may mean that the rate of fat oxidation may have reached the termination stage even before storage was started. At this stage non-radical products had been formed thus no radicals are available for further reaction with oxygen (Dugan, 1976).

In general, samples stored in the laboratory showed slightly better sensory characteristics (Table 3) than that of the market products which had lost its golden brown colour and glossy appearance. Aroma scores for smoked marine samples were not too adversely affected

Table 4. Microbiological quality of processed marine and lagoon shrimps under storage study (0 and 4 months)

Sample	pH		Total viable count/g		Mould and yeast count (cfu/g)		Coliforms (in 0.1g)		*E. coli* (in 100g)		*S. aureus* (in 5g)		Salmonella (in 25g)		Others	
	Storage time (months)															
	0	4	0	4	0	4	0	4	0	4	0	4	0	4	0	4
Market storage																
Smoked marine shrimps	7.6	7.1	$5.1x10^3$	$2.4x10^6$	< 10	$1.2x10^2$	ND	ND	ND	ND	ND	ND	ND	ND	Bacillus	Bacillus Micrococci Monilia
Sundried marine shrimps	7.5	7.2	$4.3x10^2$	$8.7x10^3$	$1.4x10^1$	$4.6x10^3$	ND	ND	ND	ND	ND	ND	ND	ND	Bacillus Mucor Enterobacter	Bacillus Mucor Corynebacterium
Smoked lagoon shrimps	7.5	7.4	$7.8x10^4$	$1.6x10^5$	$1.8x10^1$	$2.3x10^1$	D	D	ND	ND	ND	ND	ND	ND	Bacillus Micrococci Monilia Corynebacterium	Bacillus Monilia Mucor Corynebacterium
Laboratory storage																
Smoked marine shrimps	7.6	7.6	$5.1x10^3$	$8.8x10^3$	<10	<10	ND	ND	ND	ND	ND	ND	ND	ND	Bacillus	Bacillus
Sundried marine shrimps	7.5	7.5	$4.3x10^2$	$7.2x10^3$	$1.4x10^1$	$2.7x10^1$	ND	ND	ND	ND	ND	ND	ND	ND	Bacillus Mucor Enterobacter	Bacillus Micrococci Monilia
Smoked lagoon shrimps	7.5	7.5	$7.8x10^4$	$9.6x10^4$	$1.8x10^1$	$3.3x10^1$	D	D	ND	ND	ND	ND	ND	ND	Bacillus Micrococci Monilia Corynebacterium	Bacillus Micrococci Monilia

D = detected *ND = Not detected*

on storage as compared to sun-dried marine samples which registered rancid and poor flavour scores. While the sun-dried samples recorded changes in textural characteristics and became slightly tougher, the smoked marine and lagoon samples were not significantly affected by storage.

Microbiologically, laboratory stored shrimps had good keeping quality and storage characteristics than those under market storage condition. This may be attributable to high level of hygienic handling, clean equipment and storage conditions. The lower pH values recorded for market samples may be responsible for the strong ammoniacal odour observed having been as a result of the breakdown of protein in the shrimps.

There was an increase in bacterial numbers for the stored market samples from an initial value of between $4.3x10^2$ and $7.8x10^4$ orgs/g to 8.7×10^3 and 2.4×10^6 org/g, as compared to the negligible increase in values for the laboratory stored shrimps (Table 4). Mould and yeast count for market samples also increased from between <10 and 1.8×10^1 cfu/g to between 2.3×10^1 and 4.6×10^3 cfu/g over the storage period. Non-faecal coliforms were detected in the stored smoked lagoon shrimps, but no pathogenic micro-organisms were detected in either the laboratory or market samples. *Bacillus sp.* were the most prevalent organisms during storage. Although *Micrococci, Corynebacterium, Mucor and Monilia* persisted on storage, *Enterobacter sp.* which were initially isolated from the sun-dried marine shrimps before storage was not detected after the storage period. This development may be attributable to the large increase in *Bacillus sp.* which may have been antagonistic to the *Enterobacter sp.* thus preventing its further growth and proliferation.

Applications of Hazard Analysis Critical Control Point (HACCP) to the shrimp products is presented in Fig. 1 and Table 5, indicating each step of a processing scenario for the processed shrimps.

Although generically, 14 steps were identified in the processing of smoked and sun-dried shrimps, only 2 of these were found to be critical in relation to microbial pathogens and these are:

(i) Smoking and sun-drying to ensure proper thermal penetration of the shrimps.

(ii) Storage at appropriate temperature and time to prevent microbiological growth of pathogenic bacteria and moulds and hence possible toxin elaboration.

Traditional processors were found to employ the 14 steps except steps 3, 8, 9, 11 and 12 which are freshwater rinsing, inspection, grading, weighing and labelling. Seawater was used to rinse the shrimps, in certain cases, but where sand particles were not noticed in large quantities, no rinsing was carried out prior to smoking or drying. Inspection procedures, grading, weighing and labelling were non-existent. Baskets of various sizes were employed in pricing the shrimps instead of the use of weight measure. In addition, since labelling was not done, the length of storage time are not known but rather estimated; and sale of stored products was done on demand, at a period of the year when the shrimps would fetch the processor maximum income.

It was therefore observed that the processors tended to store the shrimps longer than was necessary and hence the products became degraded especially as the holding temperature of storage was not controlled.

Smoking and transportation have been classified as the most important critical control point (CCP) for this product and has been classified as CCP1 as this has been observed as steps that can ensure control of a hazard. CCP2 has been identified as the steps that minimize a hazard. Prevention of recontamination of shrimps after smoking or drying may also be considered as a critical control point. Although the HACCP concept is the best for controlling microbial hazards in shrimps from harvest to the consumption stage in the food service industry, without the education of non professional food handlers, this system may not be effective.

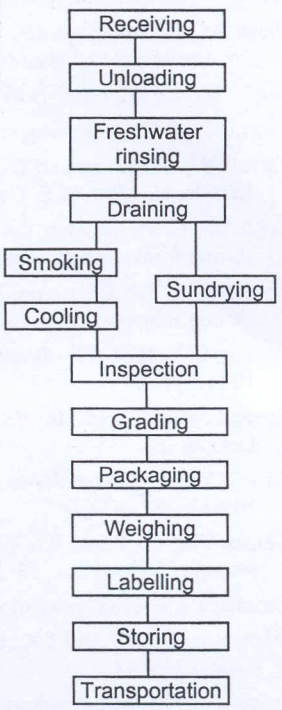

Figure 1. Flow diagram in shrimp drying and smoking.

4. CONCLUSIONS AND RECOMMENDATIONS

Generally, samples of cured *Penaeus notialis* from processing sites had lower levels of bacterial and mould contamination as well as moisture content than those obtained from the markets. Temperature and time management in storage of the shrimps help to maintain its physical and chemical characteristics. However, improper or unhygienic handling results in spoilage by micro-organisms and infestation by *Dermestes frischii* adults and larvae.

It is recommended that insect or fly-screens be constructed around and over drying racks to reduce *Dermestes* infestation pressure during processing. In addition, during storage and transport, the use of polyethylene bags to line clean good-quality sacks will slow down the rate of immigration of *Dermestes spp.* and other insects like ants. Also cross-infestation may be reduced by the avoidance of reusing such packaging material

Table 5. Critical control points for processed shrimps

Flow diagram number and step[a]	Critical control point	Type of critical control
1-4 (Receiving, unloading, fresh water rinsing, draining)	CCP2	Determination of holding temperature and time. Personal hygiene of handlers/processors.
5 (Sundrying)	CCP2	Sanitation of equipment.
6 (Smoking)	CCP1	Sanitation of equipment.
7-10 (Cooling, inspection, grading, packing)	CCP2	Temperature; personal hygiene of handlers and processors; equipment sanitation.
11-13 (Weighing, labelling, storing)	CCP2	Personal hygiene; determination of storage temperature and time; microbiological limits for shrimps.
14 (Transportation)	CCP1	Temperature, contamination.

[a] *From Figure 1.*

Since the life cycle of *Dermestes frischii* takes about 5-7 weeks, it is recommended that storage should be programmed such that intermittently light smoking or drying of the shrimps, coupled with proper hygienic and handling procedures be carried out to destroy any potential pest.

There should also be Government controlled inspection system and regulatory seafood surveillance programmes by trained personnel, aimed towards consumer safety. This system must involve shoreline sanitary surveys, patrol of harvest and processing areas, plant inspection and product evaluation.

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