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POST-HARVEST MANAGEMENT AND SPOILAGE OF TROPICAL SHRIMPS (*PENAEUS NOTIALIS*)

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

M.A. HODARI-OKAE, W.A. PLAHAR and N.T. ANNAN

ABSTRACT

Traditional shrimp processing sites and marketing centres were surveyed to evaluate the effectiveness of traditional methods of processing and storage method used.

The major processing areas that supply shrimps to markets in Accra were identified as Keta and Ada and their surrounding villages; Cotonou in the Republic of Benin, and Abidjan in La Côte d'Ivoire.

The most common shrimp species smoked and sun-dried was *Penaeus notialis*. Three plants, namely *Paspalum vaginatum, Aristida sp. and Philoxerus vermicularis* were used during traditional processing to impart an orange glossy colour to the smoked shrimps.

Statistical analysis of respondents engaged in shrimp processing showed that the trade is dominated by mostly women (98.8%) between the ages of 20-50 years with about 69.7% having had varying levels of formal education.

Quantitative aerobic bacterial load recorded for fresh shrimps was high ($2.4x10^8$ bact/g). For the sun-dried and smoked marine samples, counts were comparatively low and of value $4.3x10^2$ org/g and $5.1x10^3$ orgs/g respectively. 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 the 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 $2.4x10^6$ org/g for market samples as compared to negligible increase in values of samples stored in the laboratory over the 4 months period. Mould count for market samples also increased to between $2.3x10^1$ sand $4.6x10^3$ cfu/g over the same period. Increase in microbial count correlated with decrease in sensory quality.

Most samples of cured shrimps (smoked and sun-dried) from processing sites had comparatively lower bacterial and mould load than those obtained from marketing centres. Microorganisms isolated from the shrimps include *Enterobacter, Aeromonas, Pseudomonas, Acinetobacter, Micrococcus, Corynebacterium, Bacillus Monilia, Aspergillus and Mucor*. No pathogenic microorganism was isolated from the shrimps that will pose any public health hazard.

Unhygienic practices including personal body cleanliness as well as unclean equipment and environment at the processing and especially the marketing centres were found to contribute to the high levels of contamination of the shrimps.

Physical analysis showed no significant differences between thickness values for smoked and sun-dried marine shrimps, the smoked samples however weighed 10 times heavier than the sun-dried ones. Lengthwise, the smoked samples were twice as long as the sun-dried shrimps. Lagoon samples were about 1.5 times heavier and larger in size than marine samples.

Within each location, shrimp samples from processing sites had similar physical and chemical characteristics as those from the market centres, the major difference being in a marked increase in moisture content of samples from the markets as a result of exposure during handling and transportation to marketing centres.

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%.

All the marine smoked samples had a characteristic shrimp aroma close to fresh sweet smelling. Marine sun-dried samples exhibited an appreciable degree of deterioration in flavour, while the lagoon smoked samples possessed very high sensory scores of sweet smelling aroma and typical freshly smoked shrimp flavour with an attractive glossy appearance. The process of sun-drying exposed the shrimps to more deterioration due to oxidation, with resultant increase in FFA than the smoking process.

Improper and unhygienic management, handling and marketing procedures of the shrimps were found to lead to massive economic and financial loss to the processor and retailers alike.

A beetle, *Dermestes frischii* and its larvae were found to infest the shrimps in large numbers when improperly stored, resulting in considerable quantitative and qualitative loss.

1. INTRODUCTION

Coastal penaeid shrimps belong to the class of animals known as Crustaceans and are about 40 species divided into six genera. The most important species caught in the West African Coast and of commercial importance (Garcia and L'homme, 1977) are *Penaeus notialis* and *Parapenaeopsis atlantica*.

In Ghana, coastal penaeid shrimps are generally exploited at two stages of their life cycle: during the juvenile stage in the estuaries they are fished more or less artisanally using either fixed gears (e.g. trap-barriers and stake net barriers) or towed gears (e.g. beach seine nets). In their adult stage they are exploited on an industrial scale by trawl fishery, which catches both immature and adult shrimps. Artisanal fisherfolk employ a beach seine-net, having a fine mesh to harvest post larvae and juveniles of various small sizes from the sea and lagoons. The larger ones are smoked and the smaller sized ones are sun-dried.

Shrimps, like fish, are a good source of nutrients in the form of minerals (calcium), protein (amino acids, nucleotides) as well as chitin from which chitosan is produced.

Shrimp processing industries have sprung up in Ghana especially in towns along the Coast where fishing activities are carried out. Major problems encountered however, are the absence of logistics as to proper management of the commodity and attainment of safe standards in processing to curtail spoilage.

Processing of shrimps are carried out in two ways, namely by smoking or sun-drying. These processes impart characteristic flavour to the shrimps which together with good palatability are regarded by consumers as important factors in its use as whole meals or condiments in Ghanaian dishes. However, poor management of the shrimps from harvesting through storage leads to unacceptably high and serious economic and public health consequences, since the temperature factor is not monitored. Temperature has been identified as a critical variable in the quality of fishery products like shrimps, especially since during handling and distribution, the holding temperature vary such that it is an important need to effectively estimate shelf life at prevalent tropical temperatures during storage.

Bacterial numbers in shrimps immediately after capture is very low, and to the level of several hundred to several thousand per gramme (Kartintsev, 1981). However, after

death shrimps undergo interrelated biochemical changes, resulting in the reduction of its quality for processing. Such changes include autolysis resulting in unpleasant odour, drip as well as 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). When continued storage of the shrimps takes place, flaccidity of the body tissues begin, leading on to subsequent bacterial decomposition of the tissue.

Sensory investigations of general quality of shrimps include taste, odour and texture which reaches high levels of intensities when the shrimps are over exposed and not processed shortly. Hence storage time must be as short as possible.

Traditional processing and storage, as well as packaging of shrimps continue to be in the crude stages where the use of unconventional packaging materials are employed by processors for both the storage and retail markets. Effective monitoring, evaluation and standardization 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.

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 is not always done properly, particularly in developing countries.

Temperature is a critical variable in the quality of various foods including fishery products. Since storage/holding temperatures for shrimp in commercial handling and distribution vary, the capability to estimate shelf life at temperatures which prevail is an important need.

Cobb et al. (1977) studied short-term high temperature holding on the quality of white shrimp (*P. setiferus)* within 24h. Matches (1982) reported the effect of temperature on the decomposition of Pacific Coast shrimp (*Pandalus jordani).* Most reported work has been done on fresh cold water species held at low temperature and not on processed shrimps held at elevated temperatures. These researchers have reported dominant indigenous bacteria isolated in fresh marine shrimps to include *Flavobacterium,* Cytophaga (Koburger et al., 1975), *Arthrobacter, Bacillus, Acinetobacter, Cytophaga* (Lee and Pfeifer, 1977; Lee and Kolbe, 1982); *Vibrio* and *Moraxella* (Cobb et al., 1976). These microflora were isolated from shrimp genus such as *Penaeus, Pandalus, Metapenaeus* and *Parapeneopsis* in the Pacific, Gulf of Mexico and Texas Ponds. It was observed that for these shrimps studied, differences in microflora were due to factors such as species differences, surrounding waters and sediment, postharvest handling procedures, as well as incubation temperature.

Marine shrimp from warm waters such as is the case of the prevailing tropical conditions in Ghana, carry a microbial population that is dominated by Gram positive bacteria such as *Micrococcus,* Coryneforms and *Bacillus* (Cann 1977; Shewan, 1977 and Liston, 1980) whereas cold-water species harbour predominantly Gram-negative microbes, including *Moraxella, Acinetobacter,* Pseudomonas, Flavobacterium *and Vibrio (Cann, 1977).*

Vanderzant et al. (1970) observed that quantitatively warm water marine shrimp often show total aerobic counts of 10^6/g when captured, whereas cold-water species range from $10^2 - 10^3$/g (Zapatka and Bartolomeo, 1973).

Liston (1980) observed that the predominant yeasts on shrimps are *Rhodotorula, Candida* and Torulopsis. Korburger et al. (1975) isolated the mould of the genus *Pullularia (Aureobasidium)* from fresh marine shrimps.

In Ghana, fresh shrimps landed offshore are generally not deheaded. Carroll et all (1968) observed that removal of the heads reduced the 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 shrimps than observed for deheaded shrimps.

Spoilage of shrimps is primarily due to bacterial action, but loss of freshness preceeding spoilage involves autolytic reactions as a result of naturally occurring enzymes in shrimp muscle tissue. Cheuk et al. (1979) observed that in Penaeid shrimp, the enzyme activity was a good indication of post-harvest storage time and temperature. He observed that nucleotide catabolism in the shrimps correlated with loss of freshness when he compared the activity of adenosine deaminase and adenosine monophosphate deaminase with traditional spoilage parameters such as total volatile nitrogen, total plate count, and sensory evaluation. Fatima et al. (1981) who used other shrimp species reported similar correlations.

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

Taking into account that the major hazard in food production is microbiological contamination, the need to adopt the Hazard Analysis Critical Control Point (HACCP) concept which is a logical, simple, but highly specialized system of food control designed in a systematic fashion for preventing public health and other problems from occurring (FSIS, 1989) and it is a technique that applies to production through consumption.

This concept is a two-step system requiring extensive technological knowledge in the production, processing and end-use of the specific food products. The first step of the process is to conduct a comprehensive hazard analysis of the food relative to its intended end-use, including considerations of raw materials, ingredients, role of manipulative processes to control hazards, consumer populations at risk, and epidemiological evidence relative to the potential safety considerations of the food (Hudak-Roos and Garrett, 1988). The second step of the HACCP process is the determination of each step of a processing or distribution operation; the hazard(s) associated with each step; definition of the preventive measures that can be achieved at each processing step to minimize the hazard(s) to acceptable levels; identification of the critical control points where the hazard(s) can be controlled; determination of monitoring procedures, either by observation and/or physical measurement, which can be relied on to demonstrate control of hazards; and initiation of necessary verification procedures (including records) to ensure effectiveness of the controls (Hudak-Roos and Garrett, 1989).

Another important problem in shrimp management has been insect infestation which has often been a major problem experienced by cured shrimp processors, many of whom have resorted to applying household insecticides, or applying dyes in order to reduce infestation and damage during processing and storage. The need to introduce safe, alternative methods of infestation reduction cannot be over-emphasized. Effective education of processor has not been enforced as to dangers involved in excposing shrimps in excess during handling, processing and storage. Unsanitary conditions that prevail at processing sites can be evaluated by blowfly activity. These are notorious carriers of diseases, particularly the pathogens that cause common diseases in developing countries e.g. diarrhoea, dysentery and cholera. Food poisoning microorganisms such as *Staphylococcus aureus* and faecal indicators, belonging to Enterobacteriaceae and Vibrionaceae, have been isolated from a blowfly, *C. megacephala,* collected at processing sites (Anggawati et al., 1986). Blowflies are also thought to be involved in the transmission of tapeworm eggs, which they pick up when feeding on human and animal faeces (Lawson and Gemmell, 1985).

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-emphasized. 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 landing and processing sites in the Volta Region of Ghana was carried out by means of a questionnaire (Appendix I). The areas surveyed were Anloga, Atiteti and Keta.

The questionnaire served as a means to obtain information to identify major shrimp processing areas from which sampling was carried out for physico-chemical, microbiological and sensory analysis.

Photographs were taken to depict the traditional processing ovens and equipment used; methods of shrimp handling, smoking and drying; packaging methods employed; shrimp storage structures and methods of transportation of shrimps to marketing centres.

2.2 Survey of Shrimp Marketing Centres

A survey of Market queens in Accra involved in large scale retailing of shrimps was undertaken. A total of 5 respondents from each market was interviewed using a questionnaire.

The markets surveyed and from which samples were purchased for laboratory analysis were:

1. Tuesday market
2. 31st December Makola market
3. Agbogbloshie market
4. Malata market
5. Salaga market

2.3 Sampling

Shrimp samples of the species *Penaeus notialis* found to be most prevalent was purchased from processing and marketing centres.
Fresh shrimp samples were carried in insulated cold-storage container with ice pak while smoked and sun-dried samples were placed in labelled sterile

polyethylene bags and sealed. The sample lot from the processing and market sites were randomly selected. Five sample groups of the shrimp were obtained from each site in order to determine any quality variations in relation to the different areas.

The samples were then sent to the laboratory for physico-chemical, microbiological and sensory analysis.

For storage tests, two batches of samples for each shrimp type (smoked marine shrimps, 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 storage 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.

The processing and marketing centres and the samples obtained from each area were as follows:-

Processing Centres:
- Keta (smoked and sun-dried marine samples)
- Atiteti (smoked and sun-dried marine samples)
- Anloga (smoked and sun-dried marine and smoked lagoon samples)

Marketing Centres:
- Tuesday (smoked marine and lagoon samples and sun-dried marine samples)
- Salaga (- do -)
- Malata (- do -)
- 31st December (- do -)
- Agbogbloshie (- do -)

2.4 Microbiological quality evaluation

a. **Hydrogen Ion Concentration (pH):**

Laboratory pH meter PHM 92 (Radiometer Analytical A/S - Denmark) was used. Approximately 5g of shrimp powder was weighed into plastic pH cups and 5ml. of carbon dioxide-free distilled water was added, mixed, and left to stand for 2 minutes before measurements made with the pH meter previously calibrated using standard buffer solution of pH 4.01 and 7.00 at 25°C.

b. **Aerobic Bacteria Counts (Pour Plate Technique)**

Ten grammes of shrimp powder was weighed into sterile stomacher bags. To this 90ml. of Saline Peptone solution was added and macerated. Serial dilutions of 10^{-1} - 10^{-6} were prepared, pipetted into Plate Count Agar and incubated for 72h at 30°C (Anon, 1986).

c. **Mould and Yeast Count:**

Employing the Pour Plate Technique, 1.0ml of the 10^{-1} dilution of the shrimp suspension was pipetted into duplicate sterile petri dishes. This was pour-plated with Malt Extract Agar, mixed and incubated at 25°C for 5 days. (Anon, 1987).

d. **Enterobacteriaceae (Coliforms)**

1ml. of 10^{-1} and 10^{-2} dilutions of the shrimp suspension were pipetted into sterile petri dishes where about 5ml of Tryptone Soya Agar was added and procedures completed according to Anon, 1992a.

For direct plating out, streaks were made onto MacConkey agar plates using the stock shrimp solution. The plates were incubated at 37°C for 48h.

e. **Staphylococcus aureus**

A 5g sample of shrimp powder was aseptically weighed and placed in cooked meat medium. 0.1ml. of the undiluted stock solution was transferred to Baird-Parker's medium. The inoculum was distributed with a sterile angle bent glass rod and incubated at 37°C for 24-48h as per Anon, 1992b.

f. **Vibrio parahaemolyticus**

This was carried out as per Anon, 1982. After dilutions were prepared and incubated, streaks were made onto Thiosulfate-citrate-bile salts-sucrose

(TCBS) agar; after which biochemical verification tests were carried out.

g. Salmonella sp.

Salmonella bacteria was identified by the method of Anon, 1991. Four separate steps 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.

h. Culture Identification

Smears of growth from the plates were made on clean slides with sterile loop. These were Gram stained and viewed under the microscope to identify the morphology and Gram reaction.

i. Statistical Analysis

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).

2.5 Physical and chemical analysis of shrimps

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).

2.6. Sensory Evaluation

A quantitative descriptive sensory analysis was used to assess the sensory quality of the shrimp samples. This involved a detailed descriptive sensory evaluation of

the colour, flavour, aroma and chewiness of the shrimps, provided by expert panellists (Plahar et al., 1991). For each sample, panellists used an unstructured score card with sensory descriptions at each end of a 10cm long line 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.

2.7 Colour Development in the traditional processing of shrimps

To investigate and identify the active principles in three plants (observed during the survey) used in colouring shrimps during traditional smoking process, Ethyl alcohol extracts of the plants, namely *Aristida sp., Paspalum vaginatum* and *Philoxerus vermicularis* were made. The ethyl alcohol was 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 (T.L.C.).

2.8 Identification of insect and larvae in processed shrimps.

Adults and larvae of insects were collected from smoked and dried shrimps stored for 4 months under market conditions. The adults of the insects was identified by employing full identification key as per Peacock (1975) and by the use of a low-power microscope to observe the distinguishing characters.

The larvae forms were distinguished by their hairiness and dark colour.

2.9 Laboratory Storage of Shrimps

The shrimps were packed into sterile polyethylene bags and placed in clean sacks. These were then tied up and placed in polytanks with lids. The set up was then raised off the ground and stored at 25°C for 4 months.

3. RESULTS AND DISCUSSION

3.1 Survey:

From the survey, it was observed that the most widely used traditional processi methods to preserve shrimps were sun-drying and smoking. Two types or kir of tropical shrimps were found to dominate the retail markets. These are:

i. Freshwater shrimps and
ii. Marine shrimps

Although processing techniques involved in the two types of shrimps were fou not to be different, freshwater shrimps was found to be more attractive appearance, contained less debris and sand; and harder to the touch. On the oti hand, marine shrimps were soft and easily breakable.

Survey results indicated the major source of shrimp supply to markets in Ac to be:

i. Cotonou in the Republic of Benin
ii. Abidjan in La Côte D'Ivoire
ii. Keta and surrounding villages in the Volta Region of Ghana
iv. Ada and surrounding villages in the Greater-Accra Region of Ghana.

Penaeus notialis was found to be the most prevalent shrimp species. Statisti analysis of the results of the survey showed that 87.2% of respondents v engaged in the shrimp trade (smoking and sundrying) were between the ages 20-50 years. About 10.6% were below 20 years and 2.2% were above 50 years of a A total of 69.7% were found to have had any formal education. It was observed t 1.2% of respondents were men while 98.8% were women.

3.2 Microbiological quality of *Penaeus notialis*

Microbiological examination of the shrimps (*Penaeus notialis*) showed that m samples collected from the processing sites had lower bacterial load and her lower levels of bacterial contamination than those obtained from marketing centr

The pH of the fresh lagoon shrimps (Fig.1a) was 6.1 (Table 1) while that of smoked marine (Fig. 1b) and sundried (Fig. 1c) ranged between 7.4-7.7 (Table

Table 1: Microbiological Quality of Fresh Lagoon Shrimps from Anloga

Site of Collection	Market
pH	6.1
Total viable count/g	$2.4X10^8$
Mould and yeast count/g (cfu/g)	–
Coliforms (in 0.1g)	D
E. coli (in 0.1g)	D
S. aureus (in 5.0g)	ND
V. parahaemolyticus (in 25g)	ND
Salmonella (in 25g)	ND
Others	Enterobacter, Aeromonas, Pseudomonas, Acinetobacter, Micrococcus and Bacillus sp

D = detected

ND = not detected

Bacterial count of the fresh shrimps was high ($2.4X10^8$ bact/g) as shown in Table 1 while the smoked samples had a range of $4.7X10^2$ to $8.2X10^6$ bact/g (Table 2). The mould and yeast load recorded was between <10 to $3.1X10^2$ cfu/g (Table 2). The sundried samples had bacterial load of $4.8X10^2$ – $2.7X10^5$ cfu/g, and a mould level of <10 – $3.8X10^3$ cfu/g (Table 2).

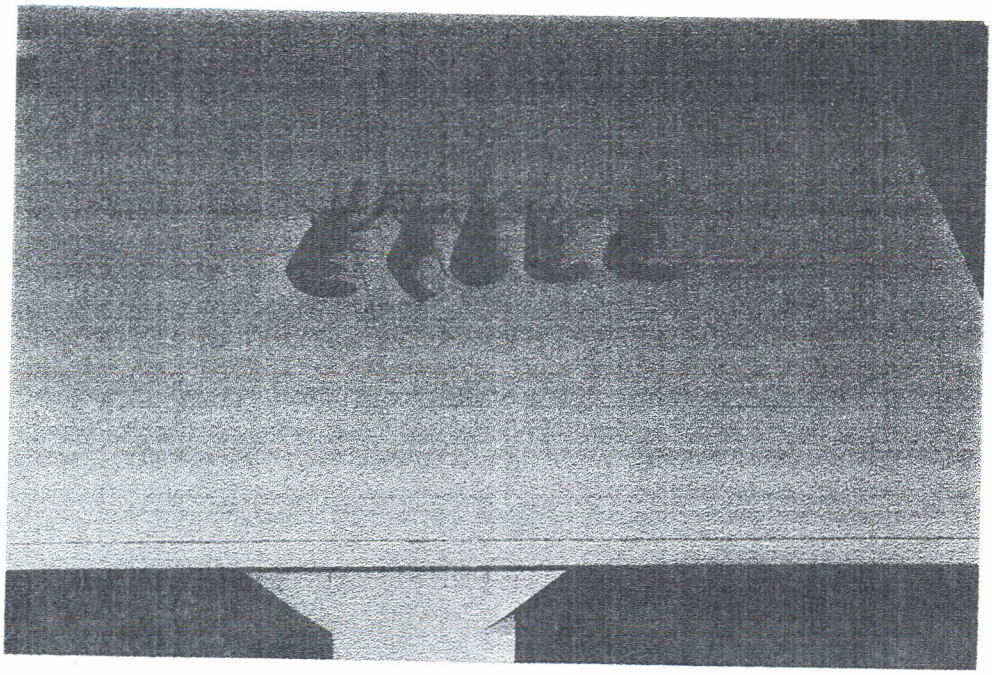


Fig. 1a. Fresh lagoon shrimps

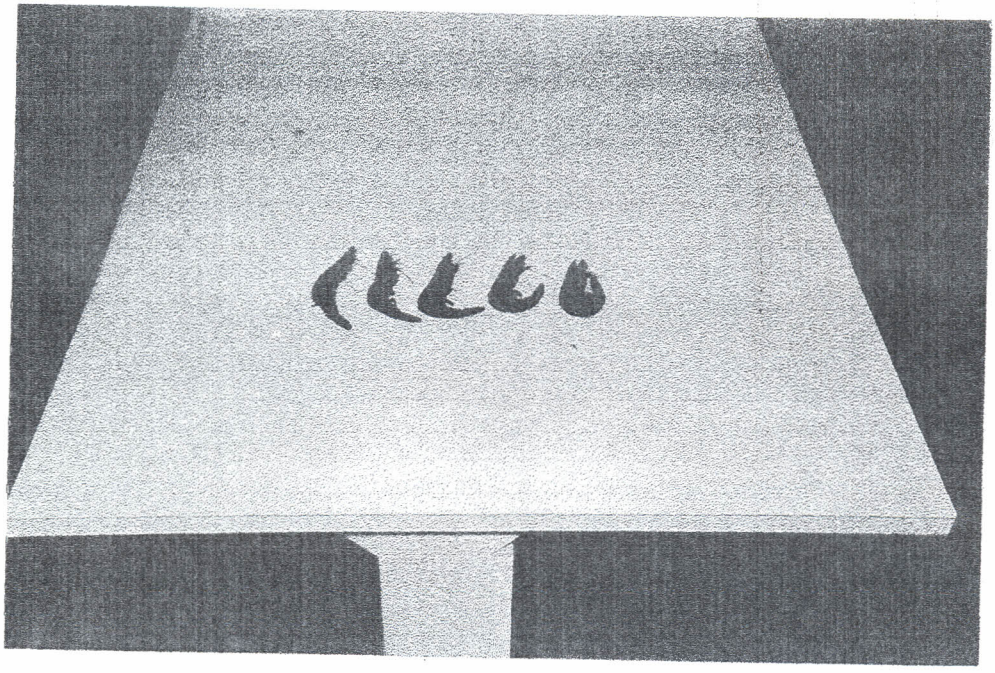


Fig. 1b. Smoked marine shrimps

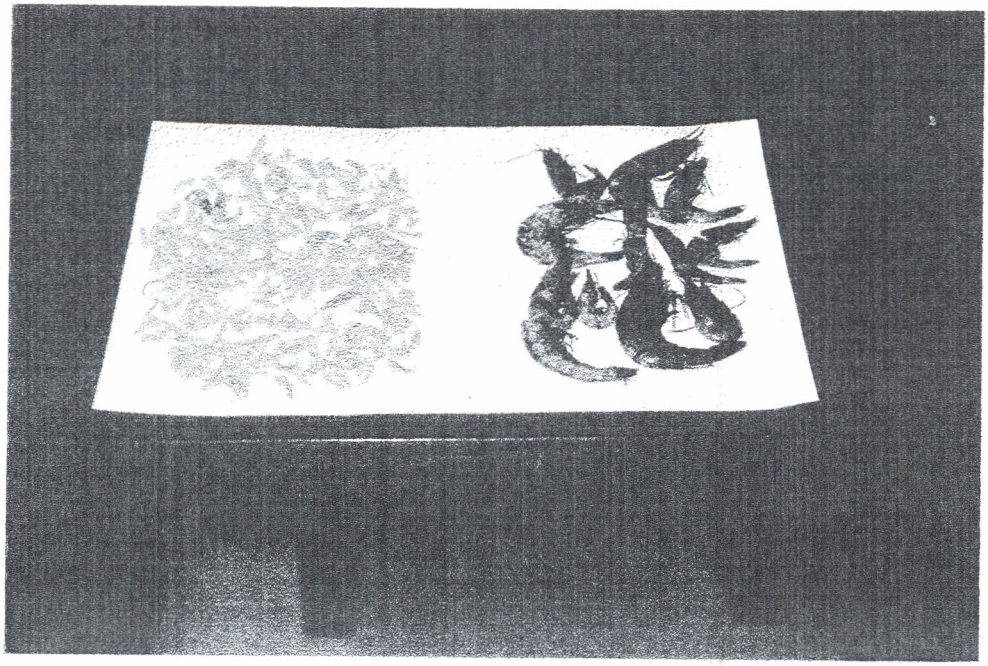


Fig. 1c. Sundried marine shrimps (left)
and smoked lagoon shrimps (right)

Table 2: Microbiological quality of processed marine shrimps from Anloga, Keta and Atiteti

Town	Anloga				Keta				Atiteti			
Type of Shrimps	Smoked		Sundried		Smoked		Sundried		Smoked		Sundried	
Site of Collection	Processing	Market	Processing	Market	Processing	Market	Processing	Market	Processing	Market	Processing	Market
pH	7.6	7.6	7.5	7.7	7.6	7.6	7.5	7.4	7.5	7.6	7.4	7.5
Total Viable Count/g	$7.4X\ 10^3$	$8.2X\ 10^6$	$5.3X\ 10^3$	$2.1X\ 10^5$	$6.4X\ 10^3$	$1.2X\ 10^4$	$4.8X\ 10^2$	$2.7X\ 10^5$	$4.7X\ 10^2$	$1.2X\ 10^3$	$6.8X\ 10^2$	$7.0X10^3$
Mould & Yeast Count/g (cfu/g)	<10	$3.1X\ 10^2$	<10	$3.6X\ 10^3$	<10	<10	$1.2X\ 10^1$	$3.8X\ 10^3$	<10	$2.6X\ 10^2$	<10	$1.0X10^1$
Coliforms (in 0.1g)	D	D	ND	ND	D	ND	ND	D	D	ND	ND	D
E. coli (in 0.1g)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
S. aureus (in 5.0g)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
V. parahaemolyticus (in 25g)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Salmonella (in 25g)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Others	Coryne bacterium Bacillus sp. Monilia	Bacillus sp., Aspergillus sp	Bacillus sp. Monilia	Aeromonas Bacillus Monilia, Aspergillus	Enterobacter Bacillus	Bacillus	Enterobacter Bacillus Mucor	Bacillus Enterobacter Coryne bacterium Aspergillus	Enterobacter Bacillus	Bacillus Aspergillus Aeromonas Coryne bact. Monilia	Bacillus Mucor	Entero Bacillus Coryne bacterium Mucor

D = Detected

ND = Not detected

Table 3 shows the microbiological quality of lagoon smoked shrimps (Fig.1c) from Accra markets which recorded a bacterial load of between $9.0X10^4$– $8.1X10^6$ bact/g of sample, while the mould level recorded was $4.6X10^1$ – $8.3x10^4$cfu/ g

Table 3: Microbiological quality of smoked lagoon shrimps from Accra markets

Site of Collection	Process-ing Site	Market Centre				
Place	Anloga	Tuesday	Salaga	Malata	31st Dec.	Agbogblo shie
pH	7.1	7.1	7.7	7.6	7.4	7.5
Total viable count/g	$8.7X10^4$	$9.0X10^4$	$6.1X10^5$	$5.7X10^6$	$9.8X10^4$	$8.1X10^6$
Mould & Yeast count/g (cfu/g)	$2.0X10^1$	$4.6X10^1$	$3.8X10^3$	$8.3X10^4$	$2.6X10^2$	$7.5X10^3$
Coliforms (in 0.1g)	ND	ND	D	D	ND	D
E. coli (in 0.1g)	ND	ND	ND	D	ND	D
S. aureus (in 5.0g)	ND	ND	ND	ND	ND	ND
V. parahaemolyticus (in 25g)	ND	ND	ND	ND	ND	ND
Salmonella (in 25g)	ND	ND	ND	ND	ND	ND
Others	Micrococci Bacillus Coryne-bacterium Monilia	Bacillus Micrococci Monilia	Bacillus Micrococci Coryne-bacterium Monilia	Bacillus Micrococci Monilia	Micrococci Coryne-bacterium Monilia	Bacillus Monilia

D = detected

ND = not detected

The increase in counts generally as recorded for samples obtained from the markets as compared with samples from processing sites may be as a result of contamination of the shrimps by exposure to dust and other environmental factors, due partly to the open air display method during sales and improper handling methods. Also packaging of the shrimps during transportation to the markets are inadequate enough to protect the shrimps from contamination during the long haul to the markets.

The pH for smoked samples from the lagoon ranged between 7.1 to 7.7

3.3 **Physical and Chemical characteristics of processed Shrimps**

The physical characteristics of smoked and sun-dried marine shrimps obtained from processing and marketing sites at different locations are presented in Table 4. The results are given as mean ± standard deviation for weight, length and thickness. Although there is no significant differences between thickness values for smoked and sun-dried marine shrimps, the smoked samples were about ten times heavier than the sun-dried samples.

Table 4: Physical characteristics of processed marine shrimps from different locations.

Processed type and Location	Collection Centre	Weight (g/100shrimps)	Length (cm)	Thickness (cm)
Smoked shrimps				
Keta	Processing	89.4 ± 24.2	4.5 ± 1.3	0.23 ± 0.05
	Market	90.2 ± 11.2	3.8 ± 1.2	0.23 ± 0.05
Atiteti	Processing	107.8 ±16.5	10.3 ± 1.5	0.47 ± 0.15
	Market	90.5 ± 8.1	9.3 ± 1.2	0.47 ±0.10
Anloga	Processing	66.0 ± 9.5	7.8 ± 0.9	0.30 ±0.10
	Market	64.2 ± 10.8	7.3 ± 1.0	0.30 ±0.10
Sundried shrimps				
Keta	Processing	5.0 ± 1.0	2.2 ± 0.10	0.20 ±0.05
	Market	4.6 ± 0.8	2.1 ± 0.15	0.15 ±0.05
Atiteti	Processing	7.8 ± 1.9	4.6 ± 1.9	0.22 ±0.08
	Market	8.6 ± 0.6	3.7 ± 0.8	0.27 ±0.05
Anloga	Processing	5.6 ± 1.4	2.4 ± 0.6	0.30 ± 0.10
	Market	6.7 ± 1.1	2.7 ± 0.7	0.20 ±0.10

Smoked samples were also about twice as long as the sun-dried ones. Values ranged between 64 and 108 g per 100 for the smoked shrimps while the sun-dried shrimps were between only 4.6 and 8.6g per 100 pieces. The lengths of the smoked samples ranged between 3.8 cm and 10.3 cm while the sun-dried samples had lengths ranging between 2.2 cm and 4.6 cm. All the shrimps examined had thickness within a range of 0.2 to 0.5 cm. An interesting observation was that within each location shrimps sampled from the processing and marketing sites had similar physical characteristics. There were however, interlocation differences, with samples from Atiteti being heavier, longer and thicker than samples from Anloga and Keta.

Lagoon shrimps were found to be heavier and larger in size than the marine samples (Fig.1c). Smoked samples of lagoon shrimps obtained from various markets in Accra were all from Anloga and ranged 133 to 161 g/100 shrimps in weight, 11.4 to 13.5 cm in length and about 0.4-0.5 cm thick (Table 5).

Table 5: Physical characteristics of smoked lagoon shrimps from Anloga

Centre	Weight (g/100shrimps)	Length (cm)	Thickness (cm)
Anloga (Processing)	189.9 ± 8.1	12.5 ± 0.9	0.50
Tuesday market	143.2 ± 5.2	13.5 ± 1.0	0.50
Salaga market	147.2± 6.2	12.5 ± 0.8	0.50
Malata market	160.6 ± 6.1	11.8 ± 0.6	0.45
31st December market	132.8 ± 6.0	11.6 ± 0.7	0.40
Agbogbloshie market	136.1 ± 9.3	11.4 ± 1.2	0.50

Samples from the processing site at Anloga had similar length and thickness to samples from the marketing centres but were much heavier. The weight difference may have been due to loss of moisture during handling and transportation from the processing site to the marketing centre. This observation is emphasized by values for moisture given in Table 7; the moisture content of market samples of smoked lagoon shrimps was about 2% less than the moisture content of samples from the processing site.

The chemical composition of smoked and sun-dried marine shrimps is presented in Table 6.

Table 6: Chemical characteristics of processed marine shrimps from different locations

Processed type and Location	Collection Centre	Moisture (%)	Protein (%)	Fat (%)	FFA (% oleic)
Smoked Shrimps					
Keta	Processing	16.2	53.0	3.1	28.4
	Market	15.9	52.9	3.1	29.0
Atiteti	Processing	15.4	53.8	2.8	26.7
	Market	15.0	53.9	2.7	21.7
Anloga	Processing	17.2	52.1	2.5	22.2
	Market	18.1	58.7	2.2	23.0
Sundried shrimps					
Keta	Processing	15.4	50.8	2.4	38.4
	Market	15.8	52.4	2.8	35.9
Atiteti	Processing	15.4	53.8	4.1	26.9
	Market	15.2	52.9	4.0	27.0
Anloga	Processing	14.0	50.8	2.4	43.2
	Market	13.9	50.4	2.7	41.9

Moisture content ranged from 14 to 18%, protein from 50 to 58.7%, while fat content ranged between 2.4% and 4.1%. Free fatty acids content of the samples was quite high ranging between 22% and as high as 43% (as oleic). Sun-dried samples were higher in FFA content than smoked samples. The process of sun-drying exposed the shrimps to more deterioration due to oxidation with the resultant increase in FFA than the smoking process. Alternatively, the smoking process may have been capable of expelling some volatile free fatty acids, as well as stabilizing fat by deposits of phenolic antioxidants from the wood smoke. For each location of sampling, shrimps from the processing sites had similar chemical characteristics as the counterparts from the market centres.

Lagoon shrimps from the various marketing centres in Accra were not significantly different in their chemical composition (Table 7).

Table 7: Chemical characteristics of smoked lagoon shrimps from Anloga

Centre	Moisture (%)	Protein (%)	Fat (%)	FFA (% oleic)
Anloga (Processing)	17.6	57.6	4.6	22.8
Tuesday market	14.9	66.7	3.5	22.2
Salaga market	14.4	67.5	3.6	22.1
Malata market	13.9	67.6	3.1	21.9
31st December market	14.0	68.0	3.1	21.9
Agbogbloshie market	14.0	68.3	3.4	22.1

Moisture content was about 14%, protein 68% and fat 3% with a free fatty acids content of about 22% (as oleic). The sample from the processing site was higher in moisture (17.6%) and fat (4.6%) with a lower protein content (57.6%).

3.4 Sensory characteristics of Processed Shrimps

Results of quantitative descriptive sensory analysis of processed marine shrimps sampled from different locations are presented in Table 8 for both smoked and sun-dried samples.

Table 8: Quantitative descriptive sensory analysis of processed marine shrimps from different locations

Processed type and location	Collection Centre	Sensory scores[1]				
		Colour	Aroma	Flavour	Chewiness	Appearance
Smoked shrimps						
.Keta	.Processing	4.5	8.2	7.0	5.5	3.0
	Market	4.0	8.0	6.5	5.0	3.0
Atiteti	Processing	4.2	8.0	6.5	5.2	3.2
	Market	4.0	8.0	6.0	5.0	3.5
Anloga	Processing	2.0	7.0	8.0	6.0	3.0
	Market	2.5	4.5	8.5	5.5	3.0
Sundried shrimps						
. Keta	.Processing	8.5	7.5	4.8	8.0	7.0
	Market	8.0	5.0	4.5	8.0	7.0
Atiteti	Processing	8.0	6.2	4.5	7.8	7.5
	Market	8.0	6.0	4.5	8.0	8.0
Anloga	Processing	8.0	5.8	4.8	8.0	7.5
	Market	8.0	5.5	4.5	7.5	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

In general the sun-dried samples were golden brown in colour and glossy in appearance while the smoked samples had colour scores close to dark brown with a relatively dull appearance. Apart from the market shrimp sample from Anloga which had a slightly off odour, all the smoked samples had an aroma close to fresh sweet smelling. Sun-dried shrimp samples had aroma scores between 5.0 and 7.5 that would describe them as neither rancid nor fresh sweet smelling. High scores were recorded for the aroma in smoked marine shrimps, having values up to 8.2. The flavour of the sun-dried samples had lower scores (4.5-4.8) than smoked samples (6.0-8.5), the description of which was close to

typically fresh. The sun-dried samples were between off flavour and typical, showing some appreciable degree of deterioration in flavour. In terms of the textural characteristics, all the smoked samples analyzed were found to be chewy while the sun-dried samples were all close to being tough in texture. High scores were also observed for the colour of marine sun-dried shrimps (8.0-8.5) as compared to (2.5-4.5) for the smoked shrimps. Chewiness scores for marine sun-dried shrimps were higher (7.5 -8.0)in contrast with (5.0-6.0) for the smoked samples.

The smoked lagoon shrimps had a brighter colour than the smoked marine species (Table 9).

Table 9: Quantitative descriptive sensory analysis of processed lagoon shrimps from Anloga

Centre	Sensory scores[1]				
	Colour	Aroma	Flavour	Chewiness	Appearance
Anloga (Processing)	6.0	9.0	8.7	5.0	8.5
Tuesday market	6.0	8.8	8.8	5.5	8.5
Salaga market	6.5	8.6	9.0	5.0	8.5
Malata market	6.5	9.0	8.8	5.0	8.0
31st December market	6.0	9.0	8.8	5.5	8.0
.Agbogbloshie market	6.0	8.6	8.0	5.5	8.5

[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

The larger size of the lagoon species perhaps prevented excessive browning during the smoking process. The smoked lagoon samples were also glossy in appearance (8.0-8.5) with sweet smelling aroma (8.6-9.0) and flavour scores (8.0-9.0) that were typical of freshly smoked shrimps as indicated in Table 9. All the smoked lagoon shrimp samples were chewy in texture.

3.5 Colour Development of Smoked Shrimps

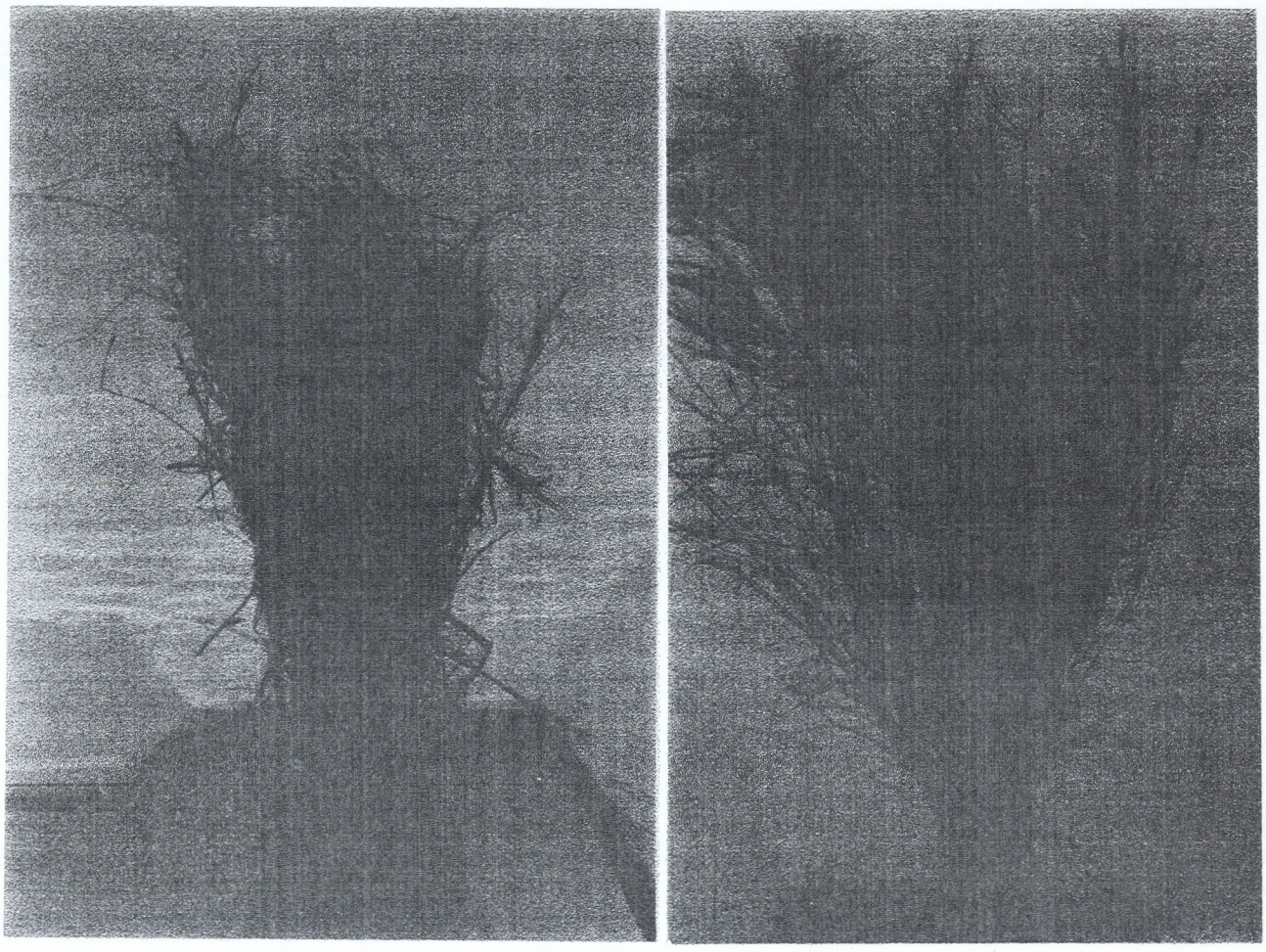
Three plants, namely *Aristida sp., Paspalum vaginatum* and *Philoxerus vermicularis (Fig.2)* were observed to be widely used in shrimp processing areas in the Volta Region of Ghana to impart a bright light orange to brown glossy colour to the shrimps (*Penaeus notialis)* during the traditional smoking process. These plants were placed in stoke holes of varying types and sizes of traditional ovens (Fig.3 and 4) and ignited to generate the smoke.

The shrimps are exposed to the smoke generated by the burning of any of the above named plants, either used singly or in combination. This results in the shrimps absorbing the smoke and developing the attractive orange colour. The active principle(s) common to these plants may be responsible for the colour development in the shrimps.

Thin Layer Chromatography (T.L.C.) results showed that the acid/neutral extracts of the three plants did not contain any compound of interest apart from traces of green pigment that may be attributed to the presence of chlorophyll. However, the basic extracts of all the three plants examined contained a compound that was detected as a dark spot under Ultra Violet (U.V.) 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.

3.6 Insect Infestation of Shrimps

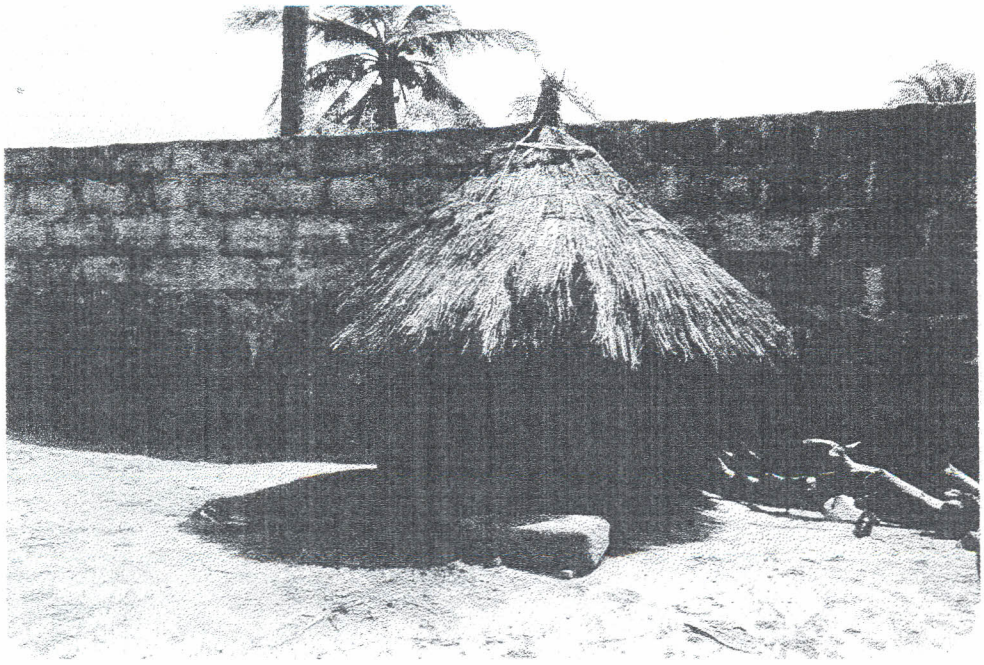
Insects were observed to infest the smoked marine shrimps stored in the market conditions far in excess of the samples stored under controlled laboratory conditions. Fewer insects were observed on the sun-dried marine shrimps under both conditions. The infestation was caused mainly by a beetle, *Dermestes frischii* and its larvae (Fig.5), while on a smaller scale ants were found to cause some damage as well. The *Dermestes sp.* belong to the insect order Coleoptera and Family Dermestidae. This species were observed to cause considerable quantitative and qualitative loss to smoked and dried cured shrimps resulting in fragmentation.



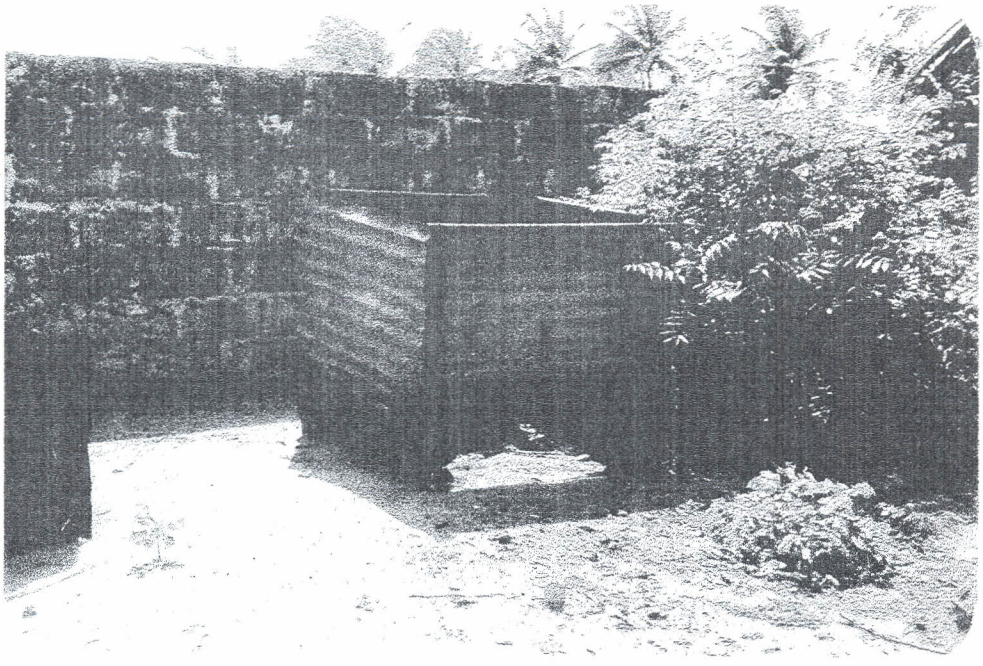
a. *Paspalum vaginatum* (local name Gbekle) b. *Aristida sp.* (local name, Gbeta)

c. *Philoxerus vermicularis* (local name, Soli)

Fig. 2. Grasses and herb used in colour development of shrimps during smoking.



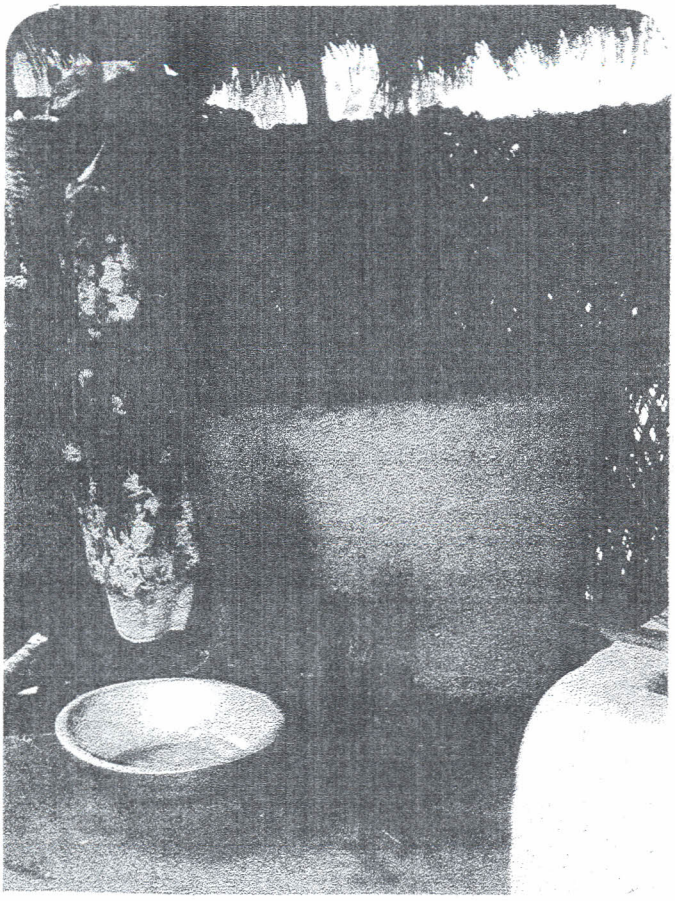
a. Round mud oven (local name, Togodo)



b. Metal Oven (local name, Akpado)

Fig.3. Type of traditional ovens used for smoking and colouring shrimps.

a. Rectangular oven (Chorkor oven) with wide stoke holes



b. Round oven with grass (*Aristida sp.*) in stoke hole

Fig.4. Improved traditional ovens with small sized wire mesh.

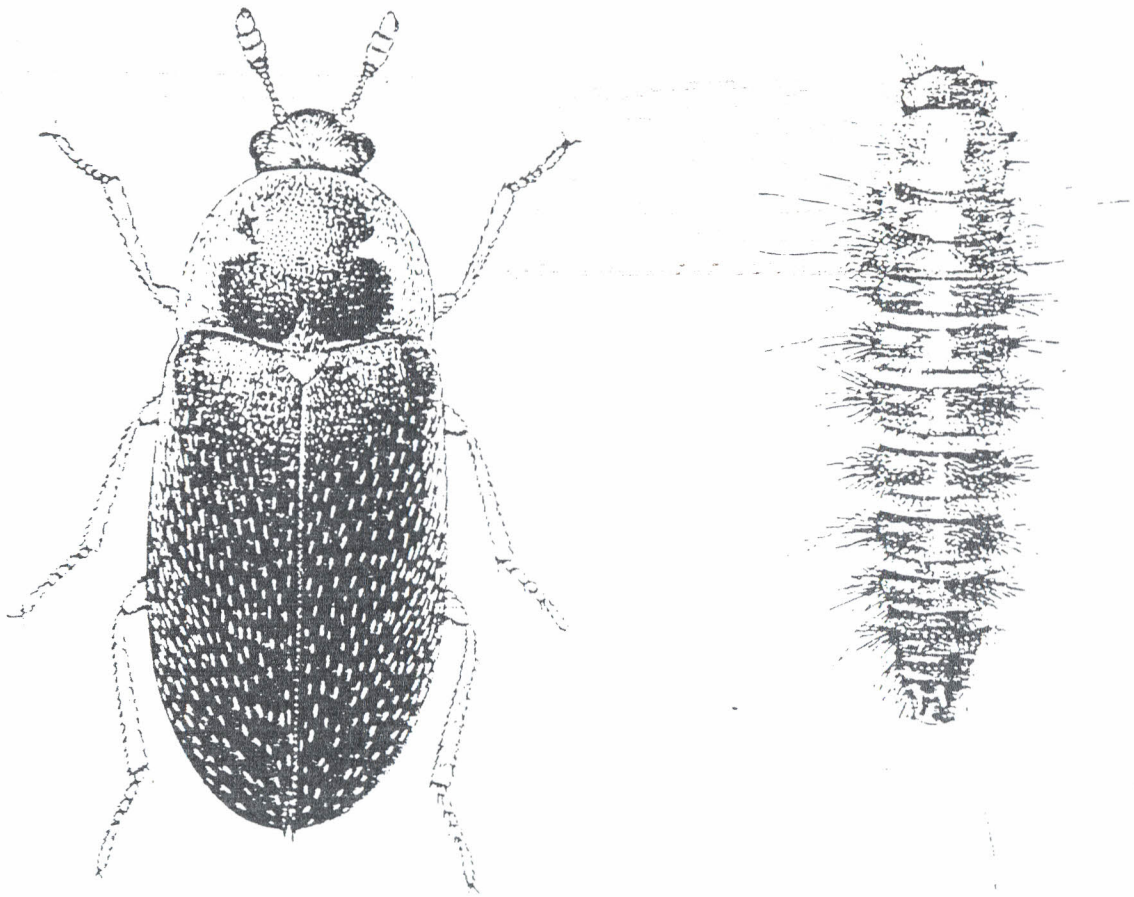


Fig. 5. Dorsal view of adult and larva of *Dermestes frischii* infesting stored shrimps.

Quality loss was also caused by the presence of insect bodies and cast skins of larvae. The extent and value of quantitative losses caused to dried fish by *Dermestes spp.* have been assessed by various investigators (Howe, 1953 ; Amos, 1968; 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 adults, which may have laid their eggs on the dried shrimps, this being enhanced by the unavailability of fly-screens around and over drying racks which may have helped to reduce *Dermestes* infestation pressure during the processing stage, as observed during the survey work. Also, it was observed that the use of clean good-quality sacks during storage and transport to the marketing centres was non-existent, as this practice may go a long way to slow down rates of immigration of the insects. Osuji (1975) found that cross-infestation by *Dermestes spp.* was reduced when jute sacks were lined with polyethylene and thick brown paper. Although from the survey, it was observed that sacks were used (Figs. 6 to 9), these sacks and paper were dirty and torn to expose the shrimps for easier access to flying adults and crawling *Dermerstes* larvae. No polyethylene bags were used to serve as a barrier. The sacks and paper were reused several times 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. 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 insecticide.

The two commonest species of *Dermestes spp.* that infest cured fish in warm climates such as in Ghana are *D. maculatus* and *D. frischii* (Coombs, 1981) with the latter being associated with marine fish and shrimps. These species have an optimum temperature in the range 30-35 °C and a minimum of 20°C; an equilibrium relative humidity of 30% or above, with their optimum being about 70% r.h. (Coombs, 1981). The prevailing ambient temperatures experienced in Ghana therefore provides *D. frischii* a convenient environment within the shrimps to proliferate.

The life cycle which takes about 5-7 weeks or longer depending on food type and physical conditions provides an increased population rate of about 30 times per month (Howe, 1953), under optimum conditions. Thus the *Dermestes* adults fly and easily disperse to new sources of food or sacks of shrimps under storage due to their large numbers.

Fig.6. Typical storage structure for shrimps (note smoke-generating wick used to drive away insects).

a. Sun-dried shrimps

b. Smoked shrimps

Fig.7. Processed shrimps packaged in sacks, brown paper and baskets for transportation to the market.

Fig.8. A typical open market scene for processed shrimps.

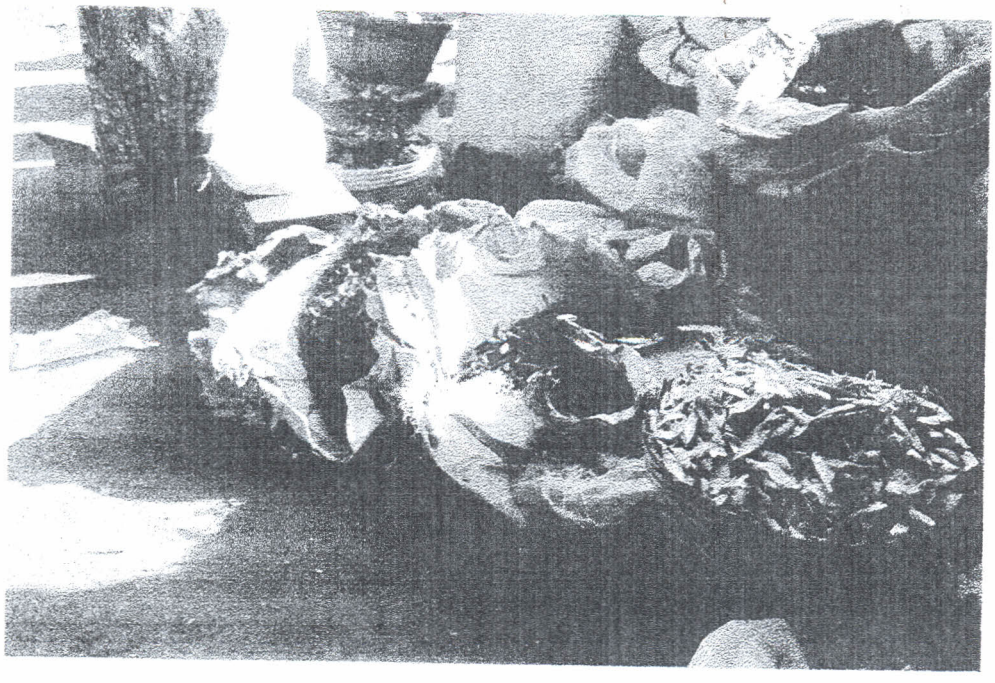


Fig.9. Display of processed shrimps for sale at the market centre.

The adults then feed on the shrimps; the larvae also burrow into the flesh as they feed on it and as they moult, leave their cast larval skins which look unsightly. This was observed on the market stored shrimps where the activities of *D. frischii* adult and larvae (Fig.10) reduced a portion (about 5%) of the stored shrimps to powder and hollow shrimp structures, the inside of which had been eaten out over the 4 months storage period. Economic loss over a longer period of storage would have been enormous considering the numbers of *D. frischii* observed and 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.

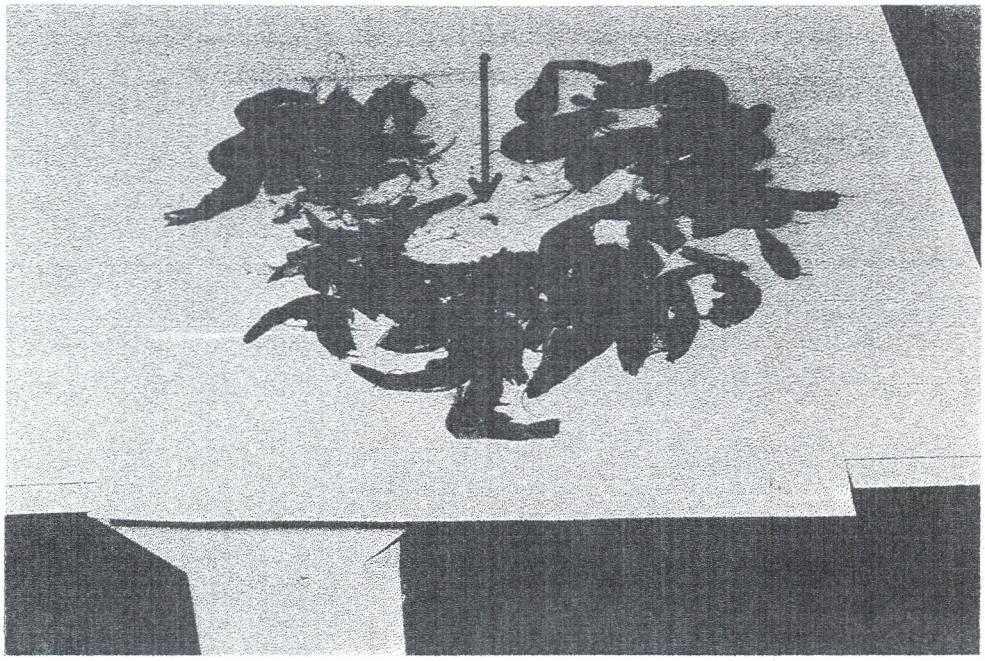


Fig.10. Larva of *Dermestes frischii* (arrowed) in stored smoke-processed shrimps.

3.7 Physical and Chemical Characteristics of Processed Shrimps

The initial physical characteristics of smoked and sun-dried marine shrimps as well as the smoked lagoon samples prepared for storage are presented in Table 10. The results are given as mean ± standard deviation for weight, length and thickness. Smoked lagoon samples were largest in size with the sun-dried marine samples being the smallest. All the samples were physically intact with no initial insect or visible mould infestation.

Table 10: Physical characteristics of processed marine and lagoon shrimps prepared for storage (Day 0).

Processed type	Weight (g/100 shrimps)	Length (cm)	Thickness (cm)
Smoked marine shrimps	89.8 ± 10.2	4.1 ± 1.3	0.22 ± 0.05
Sun-dried marine shrimps	4.8 ± 1.0	2.0 ± 0.1	0.18 ± 0.05
Smoked lagoon shrimps	141.3 ± 7.4	12.1 ± 0.7	0.45 ± 0.05

The chemical composition of the samples is presented in Table 11. The initial moisture content ranged from 14 to 16%, protein from 60 to 80%, while fat content ranged between 3.3% and 4.0%. Free fatty acids content of the samples ranged between 19% and 36% (as oleic). Sun-dried samples were higher in FFA content than smoked samples. The process of sun-drying exposed the shrimps to more deterioration due to oxidation with the resultant increase in FFA than the smoking process. Under poor storage conditions, the FFA values are expected to increase.

Table 11: Chemical composition of freshly processed shrimps under storage study (0 month storage)

Sample	Moisture (%)	Protein (%)	F a t (%)	FFA (% oleic)
Smoked marine shrimps	14.0	70.2	3.6	19.1
Sun-dried marine shrimps	15.9	62.4	3.3	35.8
Smoked lagoon shrimps	15.0	79.5	4.0	22.8

3.8 Sensory Characteristics of Processed Shrimps

Results of quantitative descriptive sensory analysis of processed marine and lagoon shrimps are presented in Table 12 for both smoked and sun-dried samples. The sun-dried sample was golden brown in colour and glossy in appearance while the smoked marine sample had colour scores close to dark brown with a relatively dull appearance. The smoked marine sample had a sweet smelling aroma while the sun-dried marine sample had aroma scores that would describe it as neither rancid nor fresh sweet smelling. Similarly, the flavour of the sun-dried sample scored lower than the smoked samples. The sun-dried sample was between off flavour and typical, showing some appreciable degree of deterioration in flavour. In terms of the textural characteristics the smoked marine sample analyzed was found to be chewy while the sun-dried marine sample was close to being tough in texture.

The smoked lagoon shrimps had a brighter colour than the smoked marine species (Table 12). The larger size of the lagoon species perhaps prevented excessive browning during the smoking process. The smoked lagoon samples were also glossy in appearance with sweet smelling aroma and flavour scores that were typical of freshly smoked shrimps. Smoked lagoon shrimp samples were found to be chewy in texture.

Table 12: Quantitative descriptive sensory analysis of processed marine and lagoon shrimps under storage study (Day 0 samples)

Processed type	Sensory Scores [1]				
	Colour	Aroma	Flavour	Chewiness	Appearance
Smoked marine shrimps	4.5	8.2	7.0	5.5	3.0
Sun-dried marine shrimps	8.5	7.5	4.8	8.0	7.0
Smoked lagoon shrimps	6.0	8.6	8.0	5.5	8.5

[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

3.9 Microbiological Quality of Processed Shrimps

The initial microbiological quality of processed marine and lagoon shrimps to be stored for 4 months under market and laboratory conditions is shown in Table 13. Analysis showed pH values of 7.6 for the smoked marine shrimps and a value of 7.5 for both the sundried marine and smoked lagoon shrimps (Table 13).

Low bacterial load was recorded for all the samples; whereas sun-dried marine sample recorded the lowest value of $4.3X10^2$ orgs/g, the smoked marine samples had $5.1X10^3$ orgs/g and smoked lagoon samples recorded a count of $7.8X10^4$ orgs/g.

Table 13: Microbiological Quality of Processed Marine shrimps and Lagoon Shrimps under Storage Study (Day 0 samples)

Processed type	Smoked Marine Shrimps	Sundried Marine Shrimps	Smoked Lagoon Shrimps
pH	7.6	7.5	7.5
Total Viable count/g	$5.1X10^3$	$4.3X10^2$	$7.8X10^4$
Mould & Yeast count/g (cfu/g)	<10	$1.4X10^1$	$1.8X10^1$
Coliforms (in 0.1g)	ND	ND	D
E. coli (in 0.1g)	ND	ND	ND
S. aureus (in 5.0g)	ND	ND	ND
Salmonella (in 25g)	ND	ND	ND
Others	Bacillus	Bacillus, Mucor, Enterobacter	Corynebacterium, Bacillus, Monilia, Micrococci

D = Detected
ND = Not detected

Negligible levels of mould and yeast counts were recorded especially for the smoked marine shrimps (<10cfu/g) while the sun-dried marine and smoked lagoon shrimps recorded $1.4X10^1$ and $1.8X10^1$ cfu/g respectively.

No coliform organisms were detected in the smoked and sun-dried marine shrimps while these organisms detected in 0.1g of the smoked lagoon shrimps were found not to be of faecal origin. This is an indication that there was no initial contamination of the shrimps by faecal matter.

No pathogenic microorganisms, namely *E. coli, S. aureus* or *Salmonella* were found in any of the shrimp samples. However, other microorganisms isolated were *Bacillus, Enterobacter, Corynebacterium, Micrococci, Mucor* and *Monilia sp.*

4.0 Effect of storage on the physical and chemical characteristics of processed shrimps

The physical characteristics of smoked and sun-dried marine shrimps as well as the smoked lagoon samples stored for 4 months in the laboratory and market are presented in Table 14. The results are given as means for weight, length and thickness. Length and thickness values for all shrimp samples did not change on storage however, significant increases in weight were observed. This may be attributed to the increase in moisture content of the shrimps during storage as shown in Table 15.

Table 14: 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

The chemical composition of the samples is presented in Table 15. Moisture content of all samples increased after storage indicating that more humid conditions prevailed during the period. Protein levels decreased by about 5% for all samples after 4 months storage both in the laboratory and market. Loss of protein occurred through breakdown to volatile components such as ammonia the odour of which was detected in the stored samples. Fat content also decreased on storage. Significant increases in free fatty acids occurred in smoked marine and lagoon shrimps after both laboratory and market storage. In the case of sun-dried shrimps the results of free fatty acid analysis did not show any significant increase over the initial high levels. This may mean that the rate of fat oxidation had reached the termination stage even before storage was started. At this stage non-radical products are formed thus no radicals are available for further reaction with oxygen (Dugan, 1976).

Table 15: 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

4.1 Effect of Storage on the Sensory Characteristics of Processed Shrimps

Results of quantitative descriptive sensory analysis of processed marine and lagoon shrimps stored for 4 months under market and laboratory storage conditions are presented in Table 16. In general, samples stored in the laboratory showed slightly better sensory characteristics than samples stored in the market. After 4 months storage sun-dried samples which were golden brown in colour had lost their glossy appearance while the smoked marine sample retained an even duller appearance. Aroma scores for smoked marine samples were not too adversely affected on storage compared to the sun-dried marine samples which had aroma scores that would describe them as rancid with consequent poor flavour scores. In terms of the textural characteristics the smoked marine and lagoon samples were not significantly affected by storage. The sun-dried samples on the other hand became slightly tougher in texture.

The smoked lagoon shrimps stored in the laboratory retained their bright, glossy appearance while those stored in the market were pale and dull. Aroma and flavour scores were not significantly changed on storage.

Table 16.: 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

4.2 Effect of storage on the microbiological quality of processed marine and lagoon shrimps

The microbiological quality characteristics of smoked and sun-dried marine shrimps as well as smoked lagoon shrimps stored for 4 months in the market and under laboratory conditions are presented in Table 17.

Compared to microbiological quality studied before storage (Day 0 samples), the laboratory stored shrimps had good keeping quality and storage characteristics than those stored under market condition. This may be attributable to the improved storage structure where the shrimps were initially enclosed in sterile polyethylene bags which were further placed in clean sacks and placed in polytanks with lids. This structure was then raised off the ground to avoid any crawling insects into the shrimps.

The pH of all the market stored samples were found to decrease while there was no change in the values for the samples stored in the laboratory. A strong ammoniacal odour of the market samples may be responsible for the low pH values. Bacterial count/g increased from initial value of between $4.3X10^{2}$and $7.8X10^{4}$ orgs/g to between $8.7X10^{3}$ and $2.4X10^{6}$ orgs/g for the market samples as compared to the negligible increase in values for the samples stored in the laboratory over the 4 months period (Table 17). The mould and yeast also increased in number after 4 months for the market stored samples from Day 0 storage values of between <10 and $1.8X10^{1}$ cfu/g to between $2.3X10^{1}$ and $4.6X10^{3}$ cfu/g over the storage period. With the laboratory stored shrimps there was no significant increase in numbers of mould and yeast organisms from the Day 0 storage values of between <10 and $1.8X10^{1}$ to between <10 and $3.3X10^{1}$ cfu/g. In the Day 0 samples only the smoked lagoon shrimps had coliform organisms detected, and this was present in the shrimps after 4 months storage period. However, *E. coli* was not isolated from any of the samples. This indicates that although coliforms were detected, there were no faecal coliforms present on the shrimps; therefore no faecal material was introduced during handling and processing of the shrimps. No pathogenic micro-organisms investigated such as *S. aureus* and *Salmonella* were detected in the shrimps after the 4 months in either the market or laboratory stored samples. However, *Bacillus sp.* were found to be the most prevalent organisms isolated on the shrimps after the 4 months storage period. Other organisms identified were

Table 17: 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/g (cfu/g)		Coliforms (in 0.1g)		E.Coli (in 0.1g)		S. aureus (in 5.0g)		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 Micro cocci Monilia
Sun-dried 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, Entero-bacter	Mucor, Bacillus Coryne bacte-rium
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	Coryne bacte-rium, Bacillus Monilia Micro-cocci	Coryne bacte-rium Monilia Mucor, Bacillus
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
Sun-dried 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, Entero-bacter	Bacillus Micro-cocci 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	Coryne bacte-rium, Bacillus Monilia Micro-cocci	Monilia Micro cocci Bacillus

D = Detected
ND = Not detected

Micrococci, Corynebacterium, Mucor and *Monilia sp. Enterobacter sp.* which were initially isolated from the sun-dried marine shrimps before storage was not detected from the samples after the 4 months storage period. This development may be attributable to the large increase in numbers of *Bacillus sp.* which may have been antagonistic to the Enterobacter sp. thus preventing further growth and proliferation of these organisms.

4.3 HACCP applications to shrimp products

The ideal process flow diagram identified during the study is presented in Fig.11, indicating each step of a processing scenario for the smoked and sun-dried shrimps. Although generically, 14 steps have been identified in the processing of smoked and sun-dried shrimps, only 2 of these have been found to be critical in relation to microbial pathogens. These are:

i. Smoking and sun-drying to ensure proper thermal penetration of the shrimps and
ii. Storage at appropriate temperature and time to prevent microbiological growth of pathogenic bacteria and moulds and hence possible toxin elaboration.

The traditional processors have been found to employ the 14 steps except steps 3, 8,9,11 and 12 namely freshwater rinsing, inspection, grading, weighing and labelling. The processors use seawater in certain cases to rinse the shrimps but in the case where they do not find much sand particles on the shrimps, no rinsing is carried out prior to smoking or drying. As for inspection procedures, grading, weighing and labelling, it is non existence. Therefore, baskets of various sizes are employed to price the shrimps instead of the use of weights measure. In addition, since labelling is not done, the length of time that the shrimps are stored are not known but rather estimated; and sale of stored products is 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.

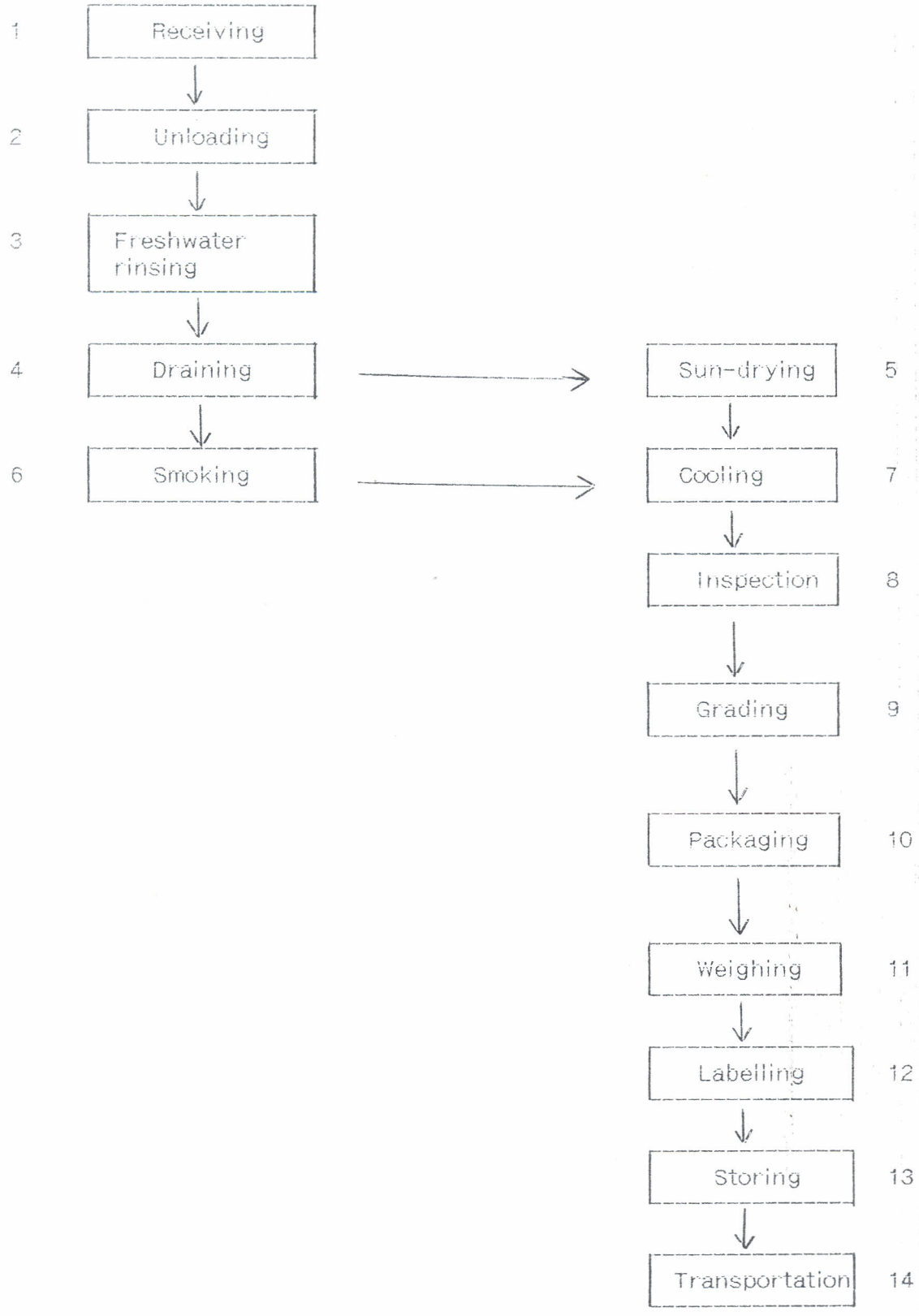


Fig. 11: Flow diagram and critical control points in an ideal smoked and dried shrimp process.

Table 18 indicates the Critical Control points for the processed shrimps.

Table 18: 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
5-6 (Sundrying and smoking)	CCP1	Sanitation of equipment
7-10 (Cooling, inspection, grading, packing)	CCP2	Temperature; personal hygiene of handlers/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 11.

Smoking, sundrying, 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.

5. CONCLUSION 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 microorganisms 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.

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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APPENDIX I - QUESTIONNAIRE FOR POST-HARVEST MANAGEMENT OF SHRIMPS

POST HARVEST MANAGEMENT OF SHRIMP
(GHANA/NETHERLANDS ARTISANAL FISH PROCESSING PROJECT)

Biodata

Questionnaire No.:
Date:

Location:

1. Name of respondent:

2. Sex:

3. Age:

4. Marital status: Married/widowed/divorced/single

5. Number of children:

6. Occupation: a) Fisherman
   b) Shrimp retailer
   c) Trader
   d) Housewife/home keeper
   e) Other (specify)

7. Level of Education:
   a) No formal education
   b) Primary school
   c) Middle school/JSS
   d) Secondary school/SSS
   e) Other (specify)

QUESTIONNAIRE FOR SHRIMP SURVEY

Harvesting of Shrimps

1. How long have you been in the shrimp industry ?

2. Do you harvest shrimps mainly or do you get it in your net as a by-product when fishing ?

3. How long does it take after harvesting to get the shrimps to the landing site ?

4. Do you wash the shrimps after harvesting ?

5. How many bumper seasons are there for shrimp harvesting (state months) ?.

6. Do you prefer shrimp harvesting to fishing ? Give reasons.

7. Do you belong to a shrimp cooperative group ?

8. What do you do to protect the shrimps from flies ?

Shrimp Processing

9. Do you process
   a) immediately after landing the shrimps ?
   b) the left-over after sales the same day ?
   c) the left-over after two days ?
   d) the left-over when it is seen to be spoiling/deteriorating ?

10. Do you keep left-over shrimps for processing the following day in any particular cold storage condition ?

11. How do you compare shrimp processing to fish processing ?
    a) Lucrative
    b) Tedious
    c) Expensive
    d) Time-wasting
    e) Other

12. How do you process your shrimps ?

a) Drying
b) Smoking
c) Other (specify)

13. Describe the process used .....
.....
.....
.....
.....
.....
.....
.....
.....
.....

14. Do you dry the shrimps before processing ?
Yes
No

15. For how long do you dry it ?

----- hour/hours
----- day/days

16. Under what conditions do you dry the shrimps ?
a) on the bare floor in the compound of my house
b) on sea sand at the shore
c) on mats spread on the floor
d) on mats placed on raised structures
e) in baskets to drain
f) on fine wire mesh

17. Do you salt the shrimps before processing ?

Yes (give reasons why) ----------

No (give reasons why) ----------

18. What traditional ovens do you use in smoking shrimps ?

19. When the shrimp is processed, what criteria do you use to show that it is dry enough for storage ?

20. What improvements in processing and equipment would you like to see for a better quality product and higher yield?

21. Do you add colour to the shrimps before processing to attract customers/consumers ?

Yes No

22. If answer to Q.21 is Yes,

a) What colour do you use ?

b) How do you go about colouring it ?

Storage of Shrimps

23. How do you store fresh shrimps before sale ?

24. What significant characteristics do you observe on the shrimps that indicate spoilage after storage for some time.

25. After processing, how do you store the shrimps ?
a) in baskets
b) polyethylene bags
c) cement paper
d) leaves (plantain, banana or other leaves)
e) jute sacks
f) other (specify)

26. Do you mix local spices to ward off insects on the stored products ?
Yes
No

27. What do you do to prevent insects and moulds on the stored shrimps ?

28. Do you intermittently dry the shrimps ?
Yes
No

29. If Yes, how ? .....
.....
.....
.....
.....
.....
.....

30. At what intervals do you dry the stored shrimps ?
a) monthly

b) every two months
c) every three months
d) six months

31. How long can you store the processed shrimps if sales are to be made for greater profit during the lean season ?

1 , 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 months

32. What problems do you encounter with the stored product ?

.....
.....
.....
.....
.....

Retailing of Shrimps

33. What type of shrimps do you retail ?
a) fresh
b) sun-dried
c) smoked
d) fermented
e) other

34. Where do you get your supply from ? (state town or fishing village)

35. What time of the year do you get your major shrimps supply ?
a) Jan - Mar
b) Apr - Jun
c) Jul - Sept
d) Oct - Dec

36. What quantity do you sell in a day ?

37. How do you transport the shrimps to the market ?

a) on the head (in open pan or basket)

b) loaded in trucks

38. Describe packaging used.....
.....
.....
.....
.....

.....

39. Do the shrimps get disfigured on reaching the market ?
    Yes
    No

40. If Q.39 is Yes, does it lead to low profit margins after sales
    Yes
    No

41. What factors do you use to price the shrimps ?

42. What is the price of an averagely small-sized basket or American tin of processed shrimps ? (give dimensions of basket)

43. Do you intend to export your products or do you aim only for the local markets ?

APPENDIX II - IDENTIFICATION CHARACTERS FOR ADULTS OF THE SPECIES OF *Dermestes* RECORDED FROM CURED FISH.

Recognition characters	*Dermestes* species (see footnote)*						
	ma.	fr.	ca.	la.	at.	ha.	pe.
Each side of thorax with a broad band of dense whitish hairs	Yes	Yes	Yes	No	No	No	No
Extreme tip of each elytron (on the mid-line) with a sharp backwardly-pointing tooth	Yes	No	No	No	No	No	No
Underside of abdomen mainly white with black spots at the sides and a larger black patch at the tip of the last segment	Yes	Yes	No	No	No	No	No
Underside of abdomen mainly white with black spots at the sides but no black patch at the tip of the last segment	No	No	Yes	No	No	No	No
Underside of abdomen entirely dark brown or black	No	No	No	Yes	No	No	No
Underside of abdomen golden brown with rows of darker brown patches at each side and on both sides of the mid-line	No	No	No	No	Yes	No	No
Underside of abdomen reddish-brown with yellowish hairs	No	No	No	No	No	Yes	Yes
Elytra evenly dark brown or black (hairs mostly black with some whitish or yellowish, or hairs mostly fine and yellowish)	Yes	Yes	No	No	Yes	Yes	Yes
Elytra with front half reddish-brown and back half dark brown; hairs mainly black with small patches of white, but with a band of golden hairs near the front of the elytra	No	No	Yes	No	No	No	No
Elytra with front half clothed in yellowish hairs, except for a dark patch at each shoulder and three pairs of dark spots across the middle; back half of elytra clothed with black hairs	No	No	No	Yes	No	No	No
Hairs on elytra coarse and quite long, projecting over the back edges of the elytra as a thick fringe; these hairs mainly dark brown or black with yellowish hairs occurring singly	-	-	-	-	-	Yes	No
Hairs on elytra fine and short, not forming a fringe on the back edges of the elytra; these hairs mainly pale yellowish	-	-	-	-	-	No	Yes

* *Dermestes* species: ma. = *maculatus*; fr. = *frischii*; ca. = *carnivorus*; la. = *lardarius*; at. = *ater*; ha. = *haemorrhoidalis*; pe. = *peruvianus*

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