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# A Review on Post-Harvest Losses in Artisanal Fisheries of Some African Countries

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## ABSTRACT

Fish is an important source of animal protein especially in African countries, where the combine forces of high cost, disease, low genetic potentials of indigenous species among other factors have raised the cost of livestock almost beyond the reach of the low income groups. Fish becomes the readily accessible source of animal protein but this alternative is also threatened by poor post-harvest techniques in African countries, which have resulted in massive losses. The losses can be physical, economical or nutritional. It is important to develop effective post-harvest technology to reduce the widening gap between fish supply and demand, which have been increasing because of poor post-harvest techniques.

**Key words:** Artisanal fish, harvest techniques, fish supply and demand, genetic potentials

## INTRODUCTION

Food security exists when all people at all the times have both physical and economic access to the basic food they need. Fisheries make an important contribution to the animal protein supplies of many communities in both the industrialised and developing worlds (Adewolu and Adeoti, 2010). It is, however, in Low-Income Food-Deficit Countries (LIFDCs), that some communities are dependent on fish, not only for animal protein, but also as a source of micronutrients, minerals and essential fatty acids. Although, theoretically, these proteins and nutrients could come from other sources, in isolated fisheries dependent communities, alternatives are likely to be more expensive, if they are available at all (FAO, 2010).

Improving food security requires making better use of fish produced by reducing post-harvest losses and increasing the percentage of fish used for direct human consumption. Post harvest losses caused by spoilage amount to about 10 to 12 million tonnes per year and in addition, It is estimated that 20 million tonnes of fish in a year are discarded at sea which is another form of post-harvest loss. Converting low-value resources, into products for direct human consumption, rather than reducing them to fishmeal, would also contribute to greater food security (FAO, 2010).

The generally acknowledged limits of production from capture fisheries, coupled with the widening gap between the supply and demand of fish for human consumption, reaffirms that post-harvest losses are an unacceptable waste of scarce natural resources. Post-harvest losses of fish occur in various forms. The physical losses of material are caused by poor handling and preservation or the discarding of bycatch. Economic losses occur when spoilage of wet fish results in a value-decrease or when there is a need to re-process cured fish, raising the cost of the finished product. In addition, inadequate handling and processing methods can reduce nutrients and leading to nutritional loss. Similarly, the lowering of large quantities of fish catches into animal feeds can be considered under certain conditions as a loss for human food security (FAO, 2010).

The need then arises to develop effective post-harvest techniques to reduce fish losses and make more fish available for human consumption.

## TYPES OF POST-HARVEST FISH LOSSES

Ames (1990) and Eyo (2001) outlined three categories of post-harvest fish losses:

**Physical losses (losses of materials):** Physical losses of fish after harvest can be regarded in two distinct ways; first, there is what might be termed complete physical loss. Quantities of fish may spoil completely and become inedible (Ames *et al*., 1991). The by-catch from shrimp trawling is thrown overboard. Related to these losses is the under-utilization of resources when small fish are converted into fish meal instead of being used for human food. Also there are many less popular fish which are seldom used for human consumption. The second type of physical loss, which can be regarded as a loss of material, is a result of poor handling and processing of both fresh and cured fish (Ames *et al*., 1991).

### Examples of complete physical loss

**Glue catches:** For many fish species, glue catches occur and then the distribution and marketing system may be unable to cope with the quantities of fish which are landed. In other places, the processing facilities such as drying racks may be inadequate. Then much of the fish has to be left to rot (Poulter *et al*., 1989).

**Losses during distribution:** Careless handling of fish can result in the fragmentation of the fish, which might make the fish to become unsaleable (Ames, 1990). Sometimes, there may be transport problems; the road could be impassable due to poor engineering/design, which often times leads to flooding, collapsing of structures like bridges and all these will simply prevent the fish from getting to the market or when it does, in a bad state that would not attract good price.

**Shrimp trawler by-catch:** When shrimp is trawled, other fishes are caught incidentally. This is known as shrimp by-catch. The proportion of by-catch is very high, often 95% or more of the total material taken on board. The by-catch is a mixture of different fish species. Usually the by-catch is thrown back into sea. However, some of it, particularly the larger fishes could be landed and sold, but even those fish are of much lower value than the shrimp. Chilled or frozen storage facilities on board the trawlers are limited, so they have to be kept for the shrimp. Also, sorting the by-catch would require a lot of the time of the trawler's crew. It is currently estimated that between 5 and 20 million tonnes per year of shrimp by-catch are wasted in this way (Ames *et al*., 1991).

**Under-utilization of small pelagic fish used for fish meal:** Fish meal is widely used, particularly in the developed countries of the world as animal feed. Fish meal is made from small pelagic fish such as sardine, mackerel and anchovy and it is estimated that some 20 million tonnes of this fish are converted into fish meal. Much of this quantity could be used directly as human food. Producing fish meal makes an indirect contribution to human food since it is used to feed animals which will then be eaten by human beings. Unfortunately, this fish has disadvantages;

it is fragile, easily spoilt and damaged so it is difficult to distribute and market in good condition. It is acceptable in canned form, but in many countries canning is expensive (Ames *et al*., 1991).

**Meso-pelagic fish:** Stocks of the more popular and accessible fish are becoming fully or over-exploited. One way of relieving the shortage of fish could be the exploitation of the less accessible meso-pelagic fish. However, practicable catching has to be developed. Also consumers are not yet familiar with this fish, so, market acceptance would also have to develop (Ames *et al*., 1991).

**Economic losses (losses in value):** The losses of material will inevitably involve a loss in value, as the fisherman, processor, or distributor has less weight of material to sell (Ames, 1990). Furthermore, the material may command a lower relative price. Dried fish which has been attacked and partly eaten by insects will be less attractive to consumers than undamaged fish and its price per kilogramme will usually be lower. Not only is there less to sell, but what can be sold is worth relatively less. Here, we have a material loss and a bigger financial loss, as someone in the chain has lost the value of the weight of fish eaten by insects and a drop in value of the remainder (Ames, 1990).

Spoilage of wet fish is accompanied by a loss in value. Consumers will pay more for fish which is in good condition. The relative value of good/fair/poor quality fish is a complicated matter and varies between countries and places. Sometimes people will pay more for fresh or iced fish and sometimes not. However, no one will pay as much for fish which is starting to become putrid as they would for fish in better condition. As fish spoils, its value drops even though this can happen in different ways. If fish can be landed and sold to the final consumer within a few hours of catching, the fish is fresh enough for this effect to be negligible. If ice is used, preferably on board or at least after landing (or after catching for land-based fishing), there is not likely to be any change in the value for many days; but if the fish cannot be iced there will normally be a quick drop in value (Ames, 1990).

Losses in material tend to be absolute, as the fish can either be sold or eaten or it cannot. Losses in value are progressive and gradual and much more subjective (Ames, 1990). Different groups of people may hold different views of the worth or value of a particular product (Ames *et al*., 1991).

In most parts of the world, fresh (wet) fish commands a higher price than traditionally cured fish (Ames, 1990). Consequently, the need to sun-dry or smoke fish in order to preserve it during the marketing cycle is itself a financial loss. The fishermen and/or those involved in the initial marketing would have received more money had it been possible to preserve the fish in ice. This type of loss is not usually included in discussions of post-harvest losses but it clearly is a loss to someone and it provides a first example of how difficult it is to define losses. However, in Nigeria, some catfish farmers smoke their fish at a relatively small size (400-600 g). The fish are harvested earlier than the conventional 5 or 6 months required for the fish to attain an average weight of 1 kg, so cost of feeding and consequently, cost of production is reduced. The smoking also enhances the shelf-life and market value of the fish, which culminates in financial gain to the fish farmer. As a matter of fact, some farmers smoke and package their fish to meet international standards and could sell them abroad to earn huge foreign exchange. This further complicates the definition of losses and factors such as geographical location may play an important role in defining post-harvest losses.

**Nutritional losses:** Nutritional losses can occur in fresh fish and some loss of nutrients is inevitable in all forms of food processing. Fish processing is no exception and in traditional methods,the losses may be serious (Mgawe, 2008). Procedures in which the fish is heated to fairly high temperatures, such as smoking, can result in damage to the nutritional value of fish protein, with losses in availability of Iysine and other essential amino acids. These losses may not be significant if the people eating the processed fish have an adequate diet in other respects. Many people in various parts of the world eat only relatively small quantities of cured fish yet may obtain enough lysine from other foods. However, many others are heavily dependent on cured fish for their protein needs. The latter are often lower income groups who may not be able to afford other protein foods richer in lysine, so this would appear to be a problem of some significance (Ames *et al.*, 1991).

As fish spoils, there will be a loss in nutritional value. The bacteria which cause the spoilage themselves eat the protein which is intended to be the main human food. This is not generally a major factor, as bacterial action generates nitrogenous substances with objectionable smells. The fish will become highly unattractive because there is too much nutritional damage. It could be more significant in freshwater fish, when less violent ammoniacal odours are produced than in marine fish, where trimethylamine and its breakdown products rapidly impart strong odours (Ames *et al.*, 1991).

## Where nutritional losses occur

**Fresh fish:** Fresh fish is extremely perishable and is subject to bacterial spoilage. As fish spoils, its nutritional value decreases, as the bacteria causing the spoilage degrade the protein which is intended for human consumption. However, bacterial action produces nitrogenous compounds with noxious odours and the affected fish will become highly unattractive because there is too much nutritional damage (Ames *et al.*, 1991).

Bacterial spoilage in fresh fish can produce toxins which cause food poisoning; histamine contamination is prevalent among pelagic fish such as mackerel and sardine. Pathogenic bacterial contamination of fresh fish caused by poor handling and washing the fish in polluted water can also cause food poisoning (Ames *et al.*, 1991).

**Cured fish:** Traditional processing of cured fish frequently involves high temperatures, particularly when the fish is smoked. It used to be thought that salting and drying effectively preserved the nutritional value of the original fresh fish and much of the older literature (Cutting, 1962) seemed to confirm this. More recent studies, particularly that carried out at the Natural Resources Institute (NRI), has indicated that this is not the case. Measurements used to be based on the gross composition of the product but now, more sensitive analytical methods are available (Ames *et al.*, 1991). It has become clear that a more appropriate measure of nutritional loss should be based on the biological availability of the muscle constituents of the fish flesh. Recent studies have shown that traditional processing methods can cause a loss of nutrient availability when fish muscle constituents, although, still physically present, are not able to he utilized by humans (Kumolu-Johnson and Abanikanda, 2001). Carpenter and Booth (1973) showed that fairly high temperatures of about 150°C as are encountered in smoking especially in Africa where hot smoking is preferred, affect the availability of lysine, one of the amino acids fount in fish protein. More recent studies carried out at Natural Resources Institute (NRI) has indicated that loss of available lysine and other essential amino acids could also occur at much lower temperatures, such as 0°C (Ames *et al.*, 1991). This raises the possibility that nutritional losses can occur when fish is sun dried.

Other nutrients present in fish muscle which can be affected by the heat used in traditional curing methods include methionine and other sulphur amino acids and vitamins K.

Rancidity development in cured fish can also lead to nutritional loss (Eyo, 2001). Rancidity is caused by the oxidation of fish lipids and so oily fishes such as sardine and mackerel are particularly prone to it. Oxidation continues during storage of cured fish, leading to the development of a bright yellow/orange colour and distinctive and unpleasant painty odour. The product will become very unattractive to consumers and may be completely rejected (Ames *et al.*, 1991).

## ARE THESE LOSSES (PHYSICAL, ECONOMICAL AND NUTRITIONAL) TRULY LOSS?

It is important to view post-harvest losses in fisheries from a broader perspective. When fish undergoes bacteriological spoilage, the loss in quality is accompanied by a reduction in commercial value. This may bring the product within the reach of low-income groups who could not afford better quality fish. The people involved in fish marketing (and perhaps the fishermen) may have suffered a loss of potential income by not selling at the best possible price, but someone else may have gained by having access to a still nutritious food. Even when fish has deteriorated so much that it cannot be sold at all and it is thrown away, there are regrettably often people who are so impoverished that they would be glad to take the least spoiled fish. This can be regarded as a loss in value for the fisherman or trader, but a social gain for very low-income groups (Poulter *et al.*, 1989).

In a different context, fish which is lost in one sense may return in another. When cured fish undergoes fragmentation, one can regard the smaller fragments as lost. These fragments are often fed to chickens and as people eat the chickens, are the fragments really lost? If one is specifically referring to losses of fish as direct human food, fragments fed to chickens must be regarded as lost (Ames, 1990).

Another form of loss is the excessive consumption of fuel by some smoking kilns. In many African countries, fuel wood supplies are under heavy pressure, leading to deforestation and soil erosion. If smoking kilns use more fuel than really necessary, the country itself suffers a loss in terms of energy resources and environment. This is not generally regarded as a post-harvest loss of fish (Ames, 1990).

## MEASURING LOSSES

Bostock (1987) reported that if an accurate assessment of losses is to be made, information needs to be obtained or collated on:

- The fish resources: the main species landed; the quantities involved and seasonal variations
- For cured fish, the types of processing techniques in use and the amount of fish processed
- For wet or cured fish, the nature of the distribution system: the destinations of the fish and by what transport systems; who is involved in distribution and marketing; how much fish is involved
- Packing systems
- Storage facilities
- Acceptability of the wet or cured fish at various product levels; the level of quality at which the fish becomes unacceptable to particular consumer groups

After the preliminary appraisal, a detailed study plan can be organized. The basic objectives to be achieved during loss assessment must be kept in view at all times. These are:

- Determination of the type of losses
- Measurements of the amount and extent of losses

## PROBLEMS OF MEASUREMENTS AND QUANTIFICATION

Many of the published figures for post-harvest losses are Estimates (Table 1). To estimate losses of cured fish due to insect infestation, the principle is fairly straightforward: how much fish have the insects eaten? The issue is not really so simple as not all the fish in a batch will have been attacked to the same extent. Some fish may be severely damaged, with a very substantial loss in weight, while others may have little visible damage. The former may be thrown away while the latter may be sold at the normal price for undamaged fish (Ames, 1990).

Many of the estimates are purely visual. Someone has looked at a lot of fish and guessed what proportion of the weight has been lost. However good the intentions, the observer's assessment can only be a guess. Often the estimates are based on the opinion expressed by processors or traders as to the quantity they lost. Few of such people are likely to have kept detailed records and the quantities they suggest may be inflated or reduced depending on the intentions of the fisherfolks (Ames *et al.*, 1991).

Another factor is that estimates are usually based on observations at a very few places on very few occasions. Quite often, someone has visited a few landing sites or markets during one or two weeks in the dry season and repeated the observations in a similar way during the wet season. The observer may conclude that losses were, say, negligible in the dry season, 20% in the wet season and therefore averaged 10% over the year. Such an approach is unscientific, even in the rare event of wet and dry seasons both lasting for six months, with uniform landings of fish throughout the year. The observer will be aware of these uncertainties and will quantify his estimates by saying that losses “may be as much as... ” or “could be about... ”. Unfortunately, such phrases are likely to be omitted when other people refer to the report or publication. When the original estimate has been referred to in a number of other publications it may become “it is generally accepted that losses are... ” (Ames, 1990).

Table 1: Some physical losses of cured fish in some African countries

| Cause | Country | Type of fish | Percent | Method of assessment | Reference |
|---|---|---|---|---|---|
| Blowflies | Malawi | Dried Unsalted | 22 | M | Walker and Donegan (1988) |
| | Sudan | Dried Unsalted | 15-30 | E | Mastaller (1981) |
| | Gambia | Dried Unsalted | 4 | M | Walker and Evans (1984) |
| Beetles | Burkina Faso | Dried Unsalted | 25 | E | Guggenheim (1980) |
| | Kenya | Dried Unsalted | 1-15 | M | Wood and Walker (1986) |
| | Mali | Dried Unsalted | 14-25 | M | Szabo (1970) |
| | Mali | Dried Unsalted | 50 | E | Duguent *et al.* (1985) |
| | Mali | Dried Salted | 9 | M | Aref *et al.* (1965) |
| | Niger | Smoked Dried | 40 | E | Bouare (1986) |
| | Nigeria | Dried Unsalted | 50 | E | Rollings and Hayward (1962) |
| | Senegal | Dried Unsalted | 30 | E | Cros *et al.* (1970) |
| | Gambia | Dried Unsalted | 4 | M | Walker and Evans (1984) |
| | Zambia | Dried Unsalted | 10 | E | Watanabe (1971) |

M: Measured, E: Estimate

Measuring losses is not an easy task. For example, in measuring blowfly losses during drying, one starts with wet fish, that is mostly water and ends with a very different product with much less water. Even if the weight of fish consumed by the insect is known, is this given as a percentage on a wet or dry basis? In considering beetle infestation of cured fish in store, allowance must be made for spontaneous changes in moisture content. The product may dry out, losing weight through dehydration as well as beetle attack. Alternatively, if the ambient humidity increases, the product may gain more weight by absorption of water than it loses through insect infestation (Ames *et al*., 1991).

Wood (1985) has drawn up a detailed scheme (Fig. 1) for assessing losses of cured fish which allows for changes in moisture, bone and salt content but it is, unavoidably, somewhat complicated. Figure 1 shows the steps involved. As for the estimates, the measurements of cured fish losses have

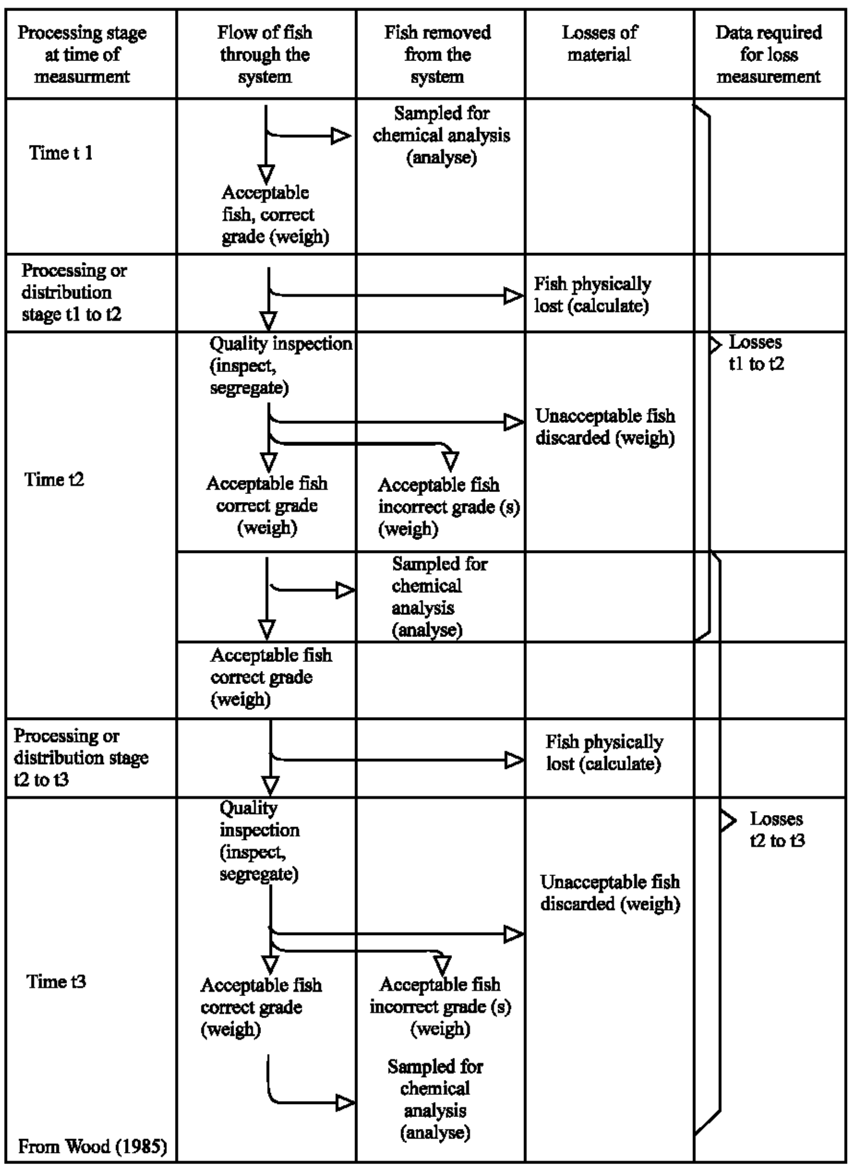


Fig. 1: Loss measurement over two consecutive processing stages

usually been carried out in a very limited number of places in the stated countries. Even if wet and dry seasons have been considered separately, it is usually only within a single year. There do not appear to have been any study of cured fish losses comparing losses in different parts of a country or on a year-by-year basis (Ames, 1990).

Spoilage losses of wet fish are also difficult to assess. In any marketing system for perishable produce, those concerned are prepared to sustain a certain proportion of losses due to spoilage. Someone who has bought a quantity of fish is likely to have a fair idea of how much he has had to throw away before selling the remainder, although comments to an outside observer may not necessarily be accurate (Ames *et al*., 1991). In a regular marketing channel, such as the distribution of wet fish in ice from the landing site to market in a distant city, the marketing system will be finely adjusted to minimize losses. Traders are not likely to sustain losses of say 50% on a regular basis, unless the price of the remaining 50% is high enough to compensate for the loss. Usually, if losses would be substantial, those concerned will improve the handling procedures, or opt for a nearer and easier market (Ames, 1990).

Spoilage of wet fish is often due to adverse weather conditions or other emergencies. If smoking is the only available means of preservation and the kilns or barbeques cannot be used in heavy rain, there may be no alternative to letting the fish spoil. Again, floods may wash away roads, preventing fish being taken to market, or preventing the wood needed for smoking to be brought to the processing sites. All these situations are likely to occur irregularly and affect specific localities, making it even harder to judge what the average level of losses might be (Ames *et al*., 1991).

## WAYS OF REDUCING POST-HARVEST LOSSES

The types of losses in fish post-harvest and the reasons for them have to be understood before any solution could be proffered. The need for assessment of losses is the first step towards overcoming losses, ways of identifying losses and defining solutions to the various post-harvest losses are the other steps that needs to be taken to solve the problem. The final stage is to describe various ways of reducing post-harvest losses in fish. These are described in detail by Clucas (1981, 1982).

Much can he achieved by simple improvements in handling and processing methods (Bolorunduro *et al*., 2005). The basic requirement is to take more care. Fish is easily damaged and easily spoiled. Careless procedures will accelerate spoilage and increase losses. Careful methods will retard spoilage, reduce losses and improve the quality of the marketed produce.

**Use of ice for fresh fish handling, distribution and marketing:** Chilling with ice is an extremely effective means of reducing spoilage in fresh fish (Akintola and Bakare, 2011). Ice is an ideal cooling medium; it is harmless, it has a very large cooling capacity for a given weight or volume, it is comparatively cheap and it is able to cool the fish quickly by intimate contact with the fish. Although, chilling can never prevent spoilage, the lower the temperature at which the fish is held, the greater the reduction of bacterial and enzymatic activity.

To chill fish, it must be surrounded by a medium which is colder than the fish itself. For effective chilling, the ice must be allowed to melt. There are additional advantages in this as melting ice keeps the fish both moist and glossy, adding to its attractiveness to the consumer. The ice melt water also helps to wash away surface bacteria and clean the fish. Ice acts as a self-thermostat and since about 80% of the total weight of fish is water, the fish is maintained at a temperature slightly above that at which it would begin to freeze. Another advantage of using ice to chill fish is that it can be transported fairly easily, as a portable cooling method.

If possible, fish should be iced on board ship, immediately after catch. Spoilage is so rapid, especially at tropical temperatures, that even a few hours delay can mean that fish is starting to spoil before landing.

Chilling in ice at sea, soon after catching, will minimize spoilage and ensure that fish is attractive and in good condition on landing.

Many fishing vessels have a hold or fish-room in which the catch can be kept in ice. Small-scale fishermen increasingly use insulated boxes to carry ice to sea and to store ice and fish. These boxes are frequently made with walls containing expanded polystyrene of about 10-15 cm thickness and they provide excellent insulation. Often, they need to be constructed to specification so that they fit into the hull of the fishing vessel. Placing them too high up might well endanger the stability of the vessel.

**Ice on shore:** If fish is iced at sea, then it is important to maintain its quality by keeping it in ice during distribution and marketing. If it is not iced at sea, it is even more important to prevent further spoilage by icing it as quickly as possible. Insulated boxes like those described above may be used for transporting the fish to market. Often, fish is loaded in ice in bulk, in open lorries.

Large insulated ice boxes may be useful at landing sites where fish has to be kept for a time before being taken to market.

**Types of ice:** The type of ice is important in chilling fresh fish in order to preserve the fish for a longer period (Kumolu-Johnson and Jimoh, 1997). Crushed or flake ice is the best, as it gives the greatest possible area of contact with the fish, ensuring that the fish is cooled quickly. With larger pieces of ice, the fish will cool more slowly. With very large pieces, such as block ice, only part of the fish will be in contact with the ice and only that part will cool quickly. While in the rest of the fish, the spoilage processes will continue for some time.

Block ice is used in many developing countries to chill fish. Smashing blocks of ice with a club or hammer gives smaller pieces but these have sharp edges which can cut into the fish. These cuts enable bacteria to penetrate the flesh more easily and spoilage is accelerated.

**Alternatives to using ice to chill fresh fish: Chilled sea water, refrigerated sea water and freezing at sea:** For larger vessels, there are two alternatives to using ice on board. Chilled sea water and refrigerated sea water. These are systems in which the fish is kept in brine, which is cooled to about 0°C. This is a bulk storage system and it is convenient for holding fish caught in large quantities at one time. The fish is landed in the wet unfrozen form.

Another alternative is freezing at sea. This is practised at the industrial level of fishing and it is usual used in tropical countries only for shrimp.

Although, ice is often a cheap product, it can be expensive in developing countries. Regardless of its effective in slowing down spoilage of fresh fish, its price can prohibit its use. Also, many fishing villages have no electricity supply and ice may not be available. The fishermen have little choice but to land fish as quickly as possible. Even so, there are some steps which can slow fish spoilage. It is useful to cover fish with sacking or other cloth, to stop direct heating by sun. Pouring water onto the sacking will cause some evaporative cooling.

**Improved drying practices:** Spoilage and loss of quality of fish can often he reduced by simple improvements in drying practices. Drying can be done on the earth, but then the fish is bound to get contaminated with dirt. Drying on mats on the ground, or on hard surface such as concrete is better. It is better still to put the fish on some sort of racks above the ground so that it is more exposed to breeze. If the rack is not too solid, say wire mesh or an old fishing net, then both sides of the fish can dry. Also, if the fish is away from the ground it is less vulnerable to domestic animals.

Fish can be smoked in any equipment which suspends the fish above a fire or in the smoke from a fire. However, in traditional smoking, the fish often gets badly charred. Various types of improved kiln exist, in which the fish is placed in racks either over the fire or in a separate smoke chamber. These make it possible to control the process, while cooking and drying the fish, without burning it.

Salting before drying or smoking can expedite processing, as salting removes much of the water from the fish. However, it gives a very different product. In much of inland Africa, salt is expensive and consumers are not accustomed to salted fish and do not readily accept it.

**Reducing insect infestation in cured fish processing and storage:** Use of salt is known in many parts of the world as an effective deterrent to blowfly infestation. Investigations have also shown that salted dried fish tends to be less susceptible to beetle infestation than non-salted fish (Khan and Khan, 2002). Although, it is generally understood that high levels of salt will be effective in reducing infestation (Kumolu-Johnson and Ndimele, 2001), it is difficult to determine the minimum effective concentration required. Moreover, it is difficult to assess whether this is a practicable method in the long term. Most of the trials have been carried out in areas where salt is not normally used and there is usually some unsalted fish nearby. It could be that blowflies merely prefer the latter, given a choice. In areas where most or all fish is salted, like Indonesia, blowflies attack salted fish very readily. Also, in areas where salting is not normally used, consumers are unfamiliar with the salty produce and may not accept it.

**Prevention of blowfly attack without insecticides:** The use of insecticides is discussed below; these are important because other methods may be ineffective. Screens can be placed over fish which is being dried and they do prevent blowflies getting to the fish. Unfortunately, they also slow down the drying process and the fish spoils. Also, blowflies have been observed to deposit their eggs on the screens, from which they drop onto the fish. Plastic greenhouses have been used but it proved virtually impossible to place the fish inside them without blowflies getting in as well.

Beetle infestation can be controlled by reprocessing. One effective method is to re-smoke stored smoked fish which has become reinfested over a hot fire. Another method, used in Malawi and in some other countries, is to immerse infested dried fish in boiling water for a few seconds and thereafter, redry them.

**Use of insecticides:** The use of contact insecticides is extremely effective against insect infestation, but it is only justified under approved and controlled conditions. Insecticides are highly toxic and many are dangerous. Only a few are safe to use on foods. One of the safe substances is pirimiphos methyl and this has been approved internationally for use on fish. It is extremely effective in controlling blowfly attack during fish drying. When used under specified conditions, it leaves no harmful residues. Pirimiphos methyl is also effective in controlling beetle infestation during storage (Khan and Khan, 2002).

**Use of fumigants:** Cured fish can be protected from beetle infestation during storage by the use of fumigants. These are insecticides existing in the gaseous form at ambient temperatures. As gases, they can diffuse into the dried fish and kill any insect infestation. It is important to remember that they do not provide lasting protection and the product can become reinfested unless suitable precautions are taken. Two of the most effective fumigants for cured fish have been found to be phosphine and methyl bromide. It is crucial to remember that as fumigants are toxic gases, they are very dangerous, so fumigation should only be carried out by trained personnel.

**Packaging:** Careful packaging with suitable plastic materials can prevent insect infestation of cured fish. However, such materials will only act as a physical barrier to insects and they will not be effective against any insects already present in the fish before it is packaged. The packaging material should be such that insects are unable to penetrate it by biting. The package should be well sealed, with holes that do not exceed 0.25 mm in diameter. Perfect sealing is possible with some sophisticated materials, but these may have the disadvantage of being expensive. Such materials may also be waterproof, encouraging mould growth. Boxes sealed with adhesive tape or lined with cloth or paper will give useful protection against insect attack, as will closely woven heavy cotton sacking, although the stitch holes in the sack are potential entry points for insects.

**Reducing mould attack:** Mould growth is encouraged by damp, so cured fish which has not been fully dried is susceptible, particularly after a period of storage (Kumolu-Johnson *et al*., 2010). Mouldy fish can be cleaned with water and redried or resmoked. Care should be exercised in the case of very mouldy fish because of the possible presence of mycotoxins (very poisonous substances produced by some moulds) (Abel-Wahhab and Kholif, 2008). Heavily salted fish is likely to absorb atmospheric moisture, so careful inspection should take place regularly, particularly during rainy seasons. The fish should be redried if it appears to be becoming moist. As a long-term measure, fish stores should be used which are designed so that they provide protection from rain and ground water and are well ventilated.

Good packaging of properly dried fish can prevent mould attack during transportation, as the fish will be kept dry. However, if plastic sheeting is used, its waterproofing properties will encourage mould growth if the fish has not been fully dried before packing. One solution is to use a woven plastic fabric which is water permeable and unlike hessian, does not become damp itself. Alternatively, the fish can be packed in a water permeable cardboard box and then protected by plastic sheeting.

**Preventing fragmentation:** Serious losses occur in cured fish from fragmentation during handling and transport, since by its very nature the fish is brittle and friable. The fish should be packed in rigid containers such as boxes or baskets with frames, which provide some protection and not in sacks or cartons which are too flexible. If baskets or similar containers are used their frames will ensure rigid protection, but if the weave is such that the fish is likely to fall through, then a lining of cloth or paper will prevent this. Cardboard or wooden boxes will protect the fish and have the advantage of being made from a single material. Rigid containers must be strong enough to be stacked without collapsing, or compressing the fish and they must be able to withstand jolting encountered in vehicles and on rough roads. Individual packages should be able to be handled easily.

Fragmentation is much more likely to occur if the fish were in poor condition before curing. The spoilage processes in wet fish gradually break down the muscle structure. Poor quality fish, even if it is dried or smoked carefully will be friable and pieces of the flesh will fall out much more easily than if the fish were fresh originally.

Preventing charring of fish can easily occur during processing. It is particularly common when very oily species such as mackerel are smoked and dried too close to the fire; the fat drips onto the fire and ignites, burning the fish.

This can be prevented by ensuring that the racks on which the fish rests above the fire are at a suitable distance from the fire and that the fish is turned regularly during processing. Charring is also caused by the smoke from the fire or kiln being too hot and so, control of combustion of the fuel should be attempted. In the simplest processes, when the fish is cured or dried over a wood fire, the wood used should be slightly damp, because then it will burn less violently and generate more smoke. If the fish is being smoked or dried in a kiln, then a well-designed kiln with flues to adjust ventilation will ensure greater control over the process.

**Good hygiene practices during fish processing:** For many types of processing, the fish must be split, gutted or cut; this often takes place on the ground or a beach, under unhygienic conditions. Often, the fish waste is allowed to collect in heaps, or it is washed into the sea or lake, causing pollution. Such conditions are ideal for bacterial growth and contamination, which accelerate spoilage.

Considerable improvements can be made by the use of simple hand-washable surfaces for cutting the fish and by regular washing down of the surfaces with clean water. The fish waste should be disposed of well away from processing areas. Contamination can be reduced if the fish is processed as soon as possible after it has been prepared and provided that it is first washed in clean water to remove any remaining viscera and blood.

If salting vats are used, they should be washed out with clean water before refilling. Drying racks and floors should be kept as clean as possible, as should all fish processing areas.

**Finding markets for by-catch:** Much of the shrimp trawler by-catch consists of fish which could be sold and used if it could be kept in good condition while being transported to market. The basic problem is its low value, especially in comparison with the shrimp itself. Small shrimp trawlers, operating on short voyages, usually ice the shrimp, but the by-catch is often left to deteriorate. On landing, priority is given inevitably to the shrimp. By the time the by-catch is taken ashore, it may be fit only for use as fish meal, which is used in animal feed. Large shrimp trawlers have freezer facilities but they keep these for shrimp and the by-catch is usually dumped overboard.

The huge potential food resource which by-catch represents has long been the subject of concern and many efforts have been made to use it. In the 1970s particularly, these efforts were concentrated on the development of manufactured products from the by-catch. The plan was that if by-catch could be converted into higher-value products, then it would become profitable for trawlers to retain and land it. Much research was carried out on the use of by-catch in making food products such as fish soups, fish biscuits, etc. (Ames *et al*., 1991). Unfortunately, very little came of this research, as there was seldom any commercial uptake of the products in question. There were two main problems. One was technical: the difficulty of producing any manufactured foodstuff from a starting material whose composition varied very substantially from day to day. The other was commercial: the limited consumer acceptance of the products in question. All too often, consumers preferred their soups or biscuits enriched with other types of protein (Ames *et al*., 1991).

## CONCLUSION

If African countries must curb food insecurity and its attendant problems like starvation, malnutrition, disease infections to mention but a few, then proper fish post-harvest technologies must be put in place to reduce losses arising from poor post-harvest techniques.

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