Final Technical Report

Project No R6824

Adaptation of systems approach to insect control.

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Summary

In tropical developing countries, insect infestation by blowflies and beetles constitutes a significant proportion of the total post-harvest losses suffered during the production of traditionally cured fish. The work conducted for this project has been concerned with the development of a prototype sustainable and fully transferable insect control strategy for use at fish processing sites in the tropics.

Unlike previous programmes of insect control, the strategy developed is systematic in its approach. This enables the underlying causes of the infestation to be identified and addressed, thereby reducing the long-term need for continuous application of control measures. The flexibility of the systematic approach enables the strategy to be fully transferable between locations, and allows for seasonal variations in the severity of infestation.

The strategy is applied by conducting an audit of infestation at each processing site. The points in the process where the infestation is initiated, and the modes by which it occurs, are determined. Any infestation risk factors associated with the processing practices followed, or the external environment at the site, are then identified in order that control measures, appropriate to the circumstances of the infestation at the site, can be selected. By separating the process into discrete stages, it is possible to quantify the severity of the infestation at each infestation point. This enables the processor to prioritise where the application of control measures is most critical to the reduction of blowfly related losses at his/her site. In combination, the important benefits afforded by the strategy should aid in its adoption by fish processors.

1.0 INTRODUCTION

In tropical developing countries, insect infestation by blowflies and beetles constitutes a significant proportion of the total post-harvest losses suffered during the production of traditionally cured fish. The work conducted for this project has been concerned with the development of a prototype sustainable and fully transferable insect control strategy for use at fish processing sites in the tropics.

Although few quantitative studies of insect related losses have been undertaken, those that have reveal that losses ranging from 5 to 90.5 % of the total fish being processed can occur, and that mean losses of 25% are common (see Johnson and Esser, 1996). These losses represent not only an economic cost to the processor and /or retailer, but also a nutritional cost owing to a reduction in the amount of processed fish available and a consequential increase in its cost. As such high losses cannot be sustained, processors and/or retailers are forced to take remedial action.

During the past forty years, several insect control methods have been evaluated for use at fish processing sites. The majority of this work has been concerned with the use of chemical control methods, in particular the use of salt to deter infestation, and insecticides to destroy feeding larvae once infestation has occurred. The effectiveness of salt in protecting the fish from infestation has been found to be highly variable (Esser, 1988; Johnson, 1997a). In some locations, good control can be achieved, but this is primarily related to local variations in influencing factors, such as the species of pest insect present, the climatic and environmental conditions at the site, and the processing practices followed (Johnson, 1997a). Once any of these variables change, the susceptibility of the salted fish to infestation increases. Salting cannot, therefore, be considered a fail-safe method of insect control.

Similarly, the use of insecticides is fraught with difficulties. At present, only two active ingredients (ai) are considered sufficiently safe to be licenced for use on fish, and one of these (piperonyl butoxide synergised pyrethrins) has been shown to be largely ineffective when used at concentrations which leave acceptable residue levels (see Walker, 1981,). Residue levels in fish treated with apparently safe concentrations of the other approved product, pirimiphos-methyl, vary considerably according to the size and lipid content of the fish being treated (Esser, 1994). Whilst it may be possible to determine safe application rates for this product on all types of fish, the requisiteness for many processors to handle mixed batches of fish is likely to mean that any attempt to introduce a range of recommended application rates will, by necessity, be violated.

Insecticides containing other ai's are generally considered unsafe when used on fish, as residues far in excess of the maximum recommended levels result from applications at even the minimum concentrations effective against the target pests. Despite this failing, many of these products are in widespread use by fish processors and retailers in many regions of the tropics (Walker, 1987). Of even greater concern are reports that many acutely toxic products which are prohibited in the West, such as DDT and lindane, are in use at some fish processing sites (Walker, 1997).

In contrast to the extensive programme of research and development carried out on chemical control measures, very little work has been conducted into alternative, non-chemical methods of insect control. Those measures which have been evaluated include screens, netting and insect-proof salting tanks and boxes, which provide a physical barrier between the fish and the pest insect (Doha, 1964; Esser, 1991; Esser, 1992). When used correctly, these methods afford 100% protection against insect pests. In spite of their efficacy, however, physical methods are not popular with fish processors. The reason for this has not been fully elucidated owing to a paucity of socio-economic data relating to control measure selection by fish processors and retailers. It is recognised, however, that most processors consider the initial cost of constructing the barrier to be too great, particularly as adequate protection can be provided by applying insecticides purchased at a fraction of the cost (Esser, 1994). As is often the case, no consideration is given by the processor to the comparative long-term costs of the two methods. In reality, the cost of constructing and maintaining a simple physical control method over a period of time, is less than the cost of using insecticides on a daily basis, where blowfly control will, almost certainly, be less than 100%.

It is apparent that the suitability, and indeed efficacy, of each of the control approaches evaluated to date is highly variable. Furthermore, the underlying cause of the infestation is not tackled. This necessitates near continual use of control measures, if all fish are to remain protected from insect-related losses. Apart from the economic consequences which arise, fish processors become trapped in a cycle of dependency. In view of these limitations, it is perhaps not surprising that processors and traders appear skeptical of any new control measures promoted. Insecticides continue to be the preferred method of blowfly control in many parts of the tropics, even in countries where their use is illegal. In many cases this is simply because the level of control they provide is sufficient to deter the processor from trying an alternative which may prove to be less effective, or more expensive to employ. However, the practice of applying insecticides to fish is highly undesirable for both health and environmental reasons, particularly when inappropriate products are employed. If processors are to be persuaded to change their practices a viable alternative must be provided.

Despite the considerable body of work which has been undertaken to devise suitable insect control measures for use on cured fish, no systematic studies of the modes and influences of infestation appear to have been conducted. If infestation is to be effectively and sustainably controlled without resorting to excessive use of insecticides, it is likely that a more systematic approach is needed. The remainder of this report details the findings of a comprehensive literature investigation into the biology and possible causes of insect infestation in traditionally processed fish, and describes a prototype control strategy developed in response to the information revealed.

2.0 DISCUSSION OF PROJECT ACTIVITIES

2.1 Secondary Data Collection and Analysis

A comprehensive review of all available information has been conducted using a wide range of data sources. The majority of this information has been generated from earlier research projects concerned with the causes and possible control of insect infestation in fisheries products. Over the past forty years this problem has been researched by both biologists and food technologists. As researchers from each discipline address the problem according to their own expertise, a broad spectrum of relevant data has arisen. Regrettably, owing to the nature of the work, much of this data has not been disseminated through scientific journals, but is reported through internal channels only. Some of the information which has been gathered outside of the United Kingdom is therefore not accessible.

As blowflies are also important economic pests in the developed world, causing myiasis in farm animals, research conducted in this area provides an important additional source of data on blowfly biology and behaviour. Until recently, control of these pests in the West has largely been through the use of chemical insecticides. Current concerns over the safety of organo-phosphorous compounds has led to research into alternative control methods, such as the use of attractant baits and infertility compounds. This information is freely available in the academic press.

The validity of the data used has been appraised in consideration of up-to date knowledge. All relevant information has been extracted and collated, and a comprehensive review document has been produced[1]. This document constitutes one of the outputs from the project. To the authors' knowledge, this document is the most comprehensive review of the biology and behaviour of insect pests of traditionally cured fish written to date. It is hoped that this document may be published and thus made available to all interested parties.

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[1] Johnson, C & Esser, J. (Eds) (1998) "A review of insect infestation in traditionally cured fish in the tropics."

The principal findings of the secondary data collection exercise can be summarised in the following points.

1. A crucial limitation of the control methods currently in use is that the underlying cause of the infestation is not tackled. This necessitates near continual use of control measures, if all fish are to remain protected from insect-related losses. Apart from the economic consequences which arise, fish processors become trapped in a cycle of dependency. This is of particular concern when insecticides are used as the primary control measure, especially where processors have resorted to the use of inappropriate products (see Walker, 1987).
2. Despite the considerable body of work which has been undertaken to devise suitable insect control measures for use on cured fish, no systematic studies of the modes and influences of infestation have been conducted. The findings of the literature review suggest that the effective and sustainable control of infestation is only likely to be achieved if a more systematic approach is taken.
3. Until recently, it has generally been considered that blowfly infestation is primarily a consequence of gravid females ovipositing upon the fish. Indirect infestation has not been considered as a serious cause of infestation. It is now apparent that, contrary to earlier beliefs, indirect infestation is an important mode of infestation at many fish processing sites where the standards of hygiene practiced are poor. Improving hygiene and processing practices at these sites, should help to eliminate much of the indirect infestation suffered.
4. In confirmation of earlier reports, the level of blowfly infestation occurring in the fish was found to be influenced by many parameters. Several parameters associated with the processing practices followed, and the external conditions at the site, have been identified. These are described in detail in the literature review document. For the benefit of this report, a brief description of each is given in the Appendix table.

Several areas where our knowledge of insect infestation is incomplete or absent were identified. These are summarised in the following points.

1. There is a paucity of information on beetle biology and behaviour. Similarly, previous studies have not considered the role external or processing parameters may play in influencing infestation levels. It is therefore not possible at present to address the control of beetle infestation by providing protection at known critical times, or by minimising the impact of any risk factors. It would thus be beneficial if subsequent research projects could focus on these shortfalls.
2. The information which is available on blowfly behaviour is largely restricted to oviposition behaviour. Additional information relating to other aspects of relevant behaviour would be of

benefit in the development of a control strategy. Two areas of particular importance are; (a) whether the absence of suitable shelter at a site decreases the risk of infestation at that site, and (b) whether immatures reared on a diet of fish are more likely to seek out fish as an oviposition medium. If shown to be significant risk factors to infestation, appropriate remedial measures could be recommended to fish processors.

3. There is very little comparative insect population data available at present. Consequently, our knowledge of seasonal population oscillations, the influence of various parameters on population dynamics, and variations in population size between individual sites and geographic locations is virtually non-existent. This information is imperative to the successful control of insect numbers at sites.
4. The information relating to the susceptibility of certain fish species to insect attack is largely anecdotal. It would be interesting to undertake statistically designed experiments to assess if the reported variations in attractiveness are accurate. If found to be valid, control measures could be directed toward those species shown to be more susceptible to attack.
5. Further work is required to appraise why control measures, other than insecticides, are not favoured by processors. This would need to involve both socio-economic and technical collaboration. It would be interesting to investigate whether processors would select physical control measures should they be given access to a loan scheme, such as those that have been introduced in some countries for village development. Evidence suggests that if an affordable loan is available, people will make use of more expensive technology, if it will improve their product and so benefit them through higher returns.
6. Whilst it is apparent that insect infestation is a continuing cause of physical and economic losses in the traditional fish processing sector in many developing countries, there is a paucity of valid loss data. This means that in many countries the true extent of these losses is not known. Furthermore, where loss evaluations have been conducted, the percentage losses reported represents the losses incurred during the limited period of the study and at the specific locations of the study. As the level of infestation varies with many factors including season and location, data generated from loss assessments has to be viewed with some caution. That said, the propensity of processors in some regions to apply insecticides to protect their fish, can be construed as evidence enough that insect infestation is a serious cause of post-harvest losses to these people. Where possible, losses data should perhaps be collected as a matter of routine in future research projects. This should include data for losses incurred at each stage of the processing and marketing chain, and during extended storage.

2.2 Development of the Control Strategy

The information gathered from the secondary data collection exercise has been used to inform the development of a prototype blowfly control strategy. The limitation in data relating to influencing factors in beetle infestation, has meant that the strategy could not be extended to include beetle control at the present time. However, there is no reason why it should not be extended in the future, should further relevant data become available.

2.2.1 Description of the Control Strategy and its Application

The strategy follows a logical system of control based upon the prevention of infestation "risk factors". These risk factors are associated with the processing practices being followed and the external conditions at the site (see Table in Appendix and the literature review document), and are known to influence the level and occurrence of blowfly infestation in traditionally cured fish. The strategy is implemented by considering the curing process systematically, from the receipt of the raw fish, through processing to the dispatch of the finished product. This takes the form of an audit conducted at the processing site in the accompaniment of the processor or an informed employee of the processor. The audit comprises five clearly defined steps:

1. identification of the processing sequence
2. determination of the timing and mode of infestation relative to the identified processing steps
3. identification of the processing risk factors that may be influencing the infestation
4. identification of the external risk factors that may be influencing the infestation
5. selection of the necessary, appropriate control measures.

The processing practices being followed for each product are identified and described by use of a process flow diagram. This enables the exact sequence of the process to be clearly defined. Each of the identified processing steps are then examined systematically to determine where in the process the infestation is occurring. These points are referred to as Infestation Points (I.P.'s). Where possible, the severity of the infestation at each I.P. is quantified in order to prioritise where control is critical, should socio-economic circumstances dictate. The mode or modes by which the infestation is occurring at each I.P. are determined by examining the fish, and the area where the fish are being held or processed, for signs indicative of direct or indirect infestation. Having identified the IP's, the processing practices up to and including the last IP can be examined for risk factors. External factors, which may be acting as risk factors, are also determined. Once the underlying causes of any infestation are known, appropriate control measures can be selected to either eliminate the risk factors, or, where this is not possible, to reduce their impact.

2.2.2 Construction of Process Charts

Example process flow diagrams have been derived for the principal processing methods followed during the production of traditionally cured fish: sun-drying alone, salting plus sun-drying, and pre-fermentation plus sun-drying (see Appendix, pp18-20). Smoking has not been included as it is highly unusual for smoked fish to be attacked by blowflies. Should the strategy be extended to incorporate beetle control in the future, it will be necessary to include an additional process chart showing smoked fish production. Owing to the wide variation in preparation practices followed by processors, even in the production of a single product, all possible combinations of preparation steps are depicted in a separate flow diagram (see Appendix, p21). The flow diagrams are provided as templates which may be amended to show the precise processing practices being followed at any site under audit. As several risk factors are associated with preparation steps, it is important that the steps being followed at the site under audit are clearly identified.

Possible Future Amendments

The flow diagrams have been devised to meet the requirements of the prototype control strategy developed as a desk study. Once the strategy is evaluated under field conditions, it may be found to be beneficial for the time taken for the fish to pass through each processing step is noted on the flow diagrams. For the purposes of the prototype strategy, however, this requirement is not specified.

2.2.3 Identification of Risk Factors

A number of processing and external risk factors were identified from the secondary data collection exercise. These are tabulated in the Appendix table. Processing risk factors were found to occur at each processing step. External risk factors were found to be associated with the rainy season, the environmental conditions at the site (temperature, relative humidity of the air and lux), and the standards of hygiene practiced at the site and in the immediate vicinity. The presence of vegetation at the site was also identified as an external risk factor, as blowflies will seek shelter amongst vegetation when the air temperature and lux readings are high. For environmental reasons, the authors felt it to be irresponsible to recommend that vegetation be removed from processing sites until field evaluations of the environmental impact of such action can be undertaken.

Without field evaluations, it is not possible to quantify the level of risk associated with each risk factor. It is most probable, however, that certain risk factors will be more important in influencing infestation than others. Whether a single risk factor will carry the same level of risk at all processing sites is not certain. This should become apparent with future field evaluations. It will also be necessary to assess whether interactions between risk factors occur. It is possible that the level of risk may appear to be equally weighted between risk factors, but that control of one may exert a controlling effect over another.

Possible Future Amendments

Additional risk factors may come to light during subsequent research or field evaluations. As the strategy is highly flexible, any necessary amendments to the list of risk factors can simply be inserted at a later date.

2.2.4 Development of Control Measures

The control measures derived to combat each of the identified risk factors are given in the Appendix table. Wherever possible, they involve manipulating the processing practices being followed in order to optimise the process and thus minimise the risk of infestation. Where this is not possible for logistical or economic reasons, previously evaluated physical control measures are recommended. For health, safety and environmental reasons, insecticides have not been included for selection. However, should their use be acceptable to the user country, the strategy can be amended to include chemical control methods. Where the effect of a risk factor may be limited in more than one way, all possible control measures have been suggested. These are listed in decreasing order of effectiveness.

The choice of a control measure should take into account any socio-economic and processing considerations. Where the application of a control measure is not feasible, it is anticipated that a reasonable reduction in the level of infestation may still be achieved if the control measures recommended to combat any other risk factors identified at the site are employed. This would need to be confirmed under field conditions, and is likely to be dependent upon the level of risk associated with the risk factor for which control cannot be applied.

Possible Future Amendments

Should additional risk factors be identified in future work, the flexibility of the strategy will enable appropriate control measures to be incorporated at a later date. Similarly, any new control measures which may be developed in the future can be added where appropriate.

2.3 Project Outputs

In addition to the comprehensive review document described above (see section 2.2.1), the project has produced two further written outputs.

2.3.1 Insect Control Schedule

The control strategy has been written up as a handbook entitled "A prototype control strategy for the reduction of blowfly infestation in traditionally cured fish in the tropics". It contains detailed instructions of how to carry out an audit at a processing site. The template flow diagrams and tables of risk factors with appropriate control measures are incorporated into the handbook to assist the auditor. The intended readership of the handbook is fisheries personnel involved in extension work and those personnel who may be trained to undertake infestation audits.

2.3.2 Manual of Best Practice

The Manual of Best Practice has been written in the form of a training manual entitled "Blowfly infestation in traditionally cured fish and its control". It is intended to provide information and training for fish processors and fisheries officers who have no formal scientific training. It comprises three volumes, each of which covers a specific topic relating to blowfly infestation and its control. Volume I provides background information on the biology of blowflies and their behaviour when infesting fish, and describes the role played by infestation risk factors. Volume II contains in depth instructions for applying the control strategy. This includes a comprehensive series of questions designed to help the reader identify any risk factors. Volume III describes the physical and chemical control measures which have been evaluated for use at fish processing sites. It includes instructions for the construction of the physical measures described. Each volume can be read independently of the others, but are complimentary to one another.

It is anticipated that the manual will provide the basis for training workshops aimed at promoting and extending the control strategy.

2.4 Socio-economic Appraisal

Hitherto loss reduction strategies for post-harvest fish processing have tended to focus upon solutions which are by definition "technically-led". That is they attempt to employ within the field situation, some product or process solution found to be effective at least within the context of some scientific experimental setting. Such specific solutions have traditionally been regarded as the pragmatic panacea to the problems of insect-infestation and have been applied with limited regard for the wider operational environment within which normal usage might occur. Many reasons may be forwarded for this emphasis in approach. For example, the constraints of resources available to deal with the central and most obvious manifestation of the problem: the loss of fish product during raw material transformation, commonly demands that only the seemingly more immediate concern is addressed.

Apart from the pressures of budgetary constraints, alternative and further dimensions of the problem are often much less readily identifiable and thus remain unexplored. As is the case with any new product or process launched into the market it takes not only time for diffusion of the innovation to occur it also takes users some time to appreciate and thus adopt, possibly adapting, the process.

Where the focus tends to be upon the initial effectiveness of the product or process this can result in seeming initial success only latterly being manifest as failure. The author is of the opinion that such a myopic focus, albeit induced for understandable reasons, has contributed to the limited success observed of many otherwise apparently apposite treatments. If projects are to be more efficient and effective in utilising scarce project resources it is necessary to avoid such situations.

It is contended that if problems such as those outlined above are to be overcome a more pragmatic approach to the initial and fundamental problem is required. Rather than only identify the technical solution to the problem of insect infestation, consideration must also be given to the wider dimensions that will embrace the users' perceptions of both the problem and solution. Necessarily this combination tends to be multi-dimensional and consequently time consuming to investigate. Moreover it will need to draw upon a multi-disciplinary skills base rather than just those emanating from a natural science/ technical persuasion.

The approach taken in this project seeks to adopt a more holistic perspective to the problems of loss reduction due to insect infestation. Such an approach demands consideration of the day-to-day, rather than the limited and somewhat artificial experimental, environment in which proposed solutions are normally evaluated. Necessarily this consideration embraces the various actors and their associated roles and influences in the decision-making processes that will determine acceptance, modification or rejection of the phenomena under investigation.

However it is argued that if alternative products or processes are to be in any way effective it is vital that the pre-conditions for processors' acceptance are 1) reviewed, 2) explored, 3) accounted for and 4) demonstrated (READ). Incorporation of these components essentially aims to ensure that the wider circumstances of the processors' operational environment are taken into account. Through the process of READ, new product and process options should have better chances of survival since the decision to launch is not just based upon technical criteria alone but instead integrates the prospective innovation within the proposed operating environment. In proposing this more holistic framework some further exposition of the concept is required before consideration of its application in practice.

Notwithstanding the importance of the various considerations outlined above and the implications for the type of data gathered, the most important aspect determining the success of the project spend is the uptake and diffusion of the idea beyond the initial lifespan of the experimental phase. Day to day users communicating by word of mouth represent the most convincing and effective communications tool in most project settings. Workshops to explain the experimental basis and the product/ process concept are invaluable in promoting transparency and understanding amongst interested parties.

However such presentations are likely to be much more effective where they reflect the more holistic perspective taken within this project approach.

Moreover effectiveness can be enhanced further still where the product concept is embodied within the daily routine of channel members perceived to be amongst the more successful. Where this can be nurtured, diffusion of the improved practice tends to filter out to the less innovative members, at which point real progress with the problem of reducing insect infestation can be said to have been achieved.

Conclusions

There are many facets of socio-economic phenomena that should be incorporated within the overall assessment process of alternatives to losses due to insect infestation. The central tenor must be recognition of the need to consider the marketing chain environment within which raw material transformation takes place, and wherein the technical solutions are to be adopted. Only by taking account of the various issues highlighted by analysis of the financial and non-financial data, and especially the various user groups, can there be realistic hope for improving upon current practice.

3.0 Summary and Conclusions

The prototype control strategy developed for this project offers processors of traditionally cured fish a flexible and sustainable way to control blowfly infestation in their product. By providing processors with the means to select control measures appropriate to the particular circumstances of infestation at their site, a high level of control should be achieved. Furthermore, the underlying causes of the infestation will be tackled thereby reducing the need to apply some control measures over time. Prioritising where control is most needed, and, where available, offering a choice of effective control measures, processors will be in a position to adopt those measures applicable to their particular socio-economic circumstances. In this way, the economic limitations which hindered the application of previous control measures may be overcome.

It is anticipated that the control strategy can be applied in all situations where blowfly infestation is a cause of post-harvest losses. The level of control achieved will be dependent upon: (i) the blowfly population size at the site, (ii) the number of risk factors implicated and how easy their impact is to limit, (iii) how many of the recommended control measures are applied, and (iv) whether the control measures selected are the most effective of those recommended. As environmental and seasonal factors are important influences of blowfly infestation, it will be necessary to monitor the situation at a site throughout the year in order that any necessary changes can be made to the control system in place.

The initial audit should be conducted by a trained extension worker, who has an understanding of blowfly biology and behaviour. Subsequent audits can be undertaken by processors providing full training is given. The training manuals described have been written for this purpose.

Without field assessments it is not possible to accurately forecast how effective the strategy will be under field conditions. Some of the suggested control measures may need to be revised and additional measures developed to increase the level of control. It is unlikely that 100% control can be achieved by following the strategy unless fish are physically protected throughout processing and into storage. As few processors are willing or able to provide this amount of protection for their fish, low levels of infestation must be expected. Infestation levels should not, however, exceed those currently incurred when insecticides are used as the sole form of control, and in many cases levels will be greatly reduced.

Whilst the development phase of this project has been wholly successful, it is essential that the concepts on which the strategy is based are fully evaluated under field conditions. This should include both rainy and dry season conditions. Any evaluation stage must also include an extensive socio-economic appraisal of the current situation and the economic implications of change.

For the strategy to succeed, processors must be persuaded to change from their current control practices to those suggested in the strategy. Where insecticides have been the principal control method used, it is probable that some resistance will be encountered. Again, field evaluations of the socio-economic implications of change are required before the strategy can be promoted. Assuming the result of any such survey is positive, it will be essential that processors are involved in educational workshops where their views can be heard and points arising incorporated into the strategy. Uptake can be advanced if those processors deemed by their peers to be the most successful are willing to adopt the strategy.

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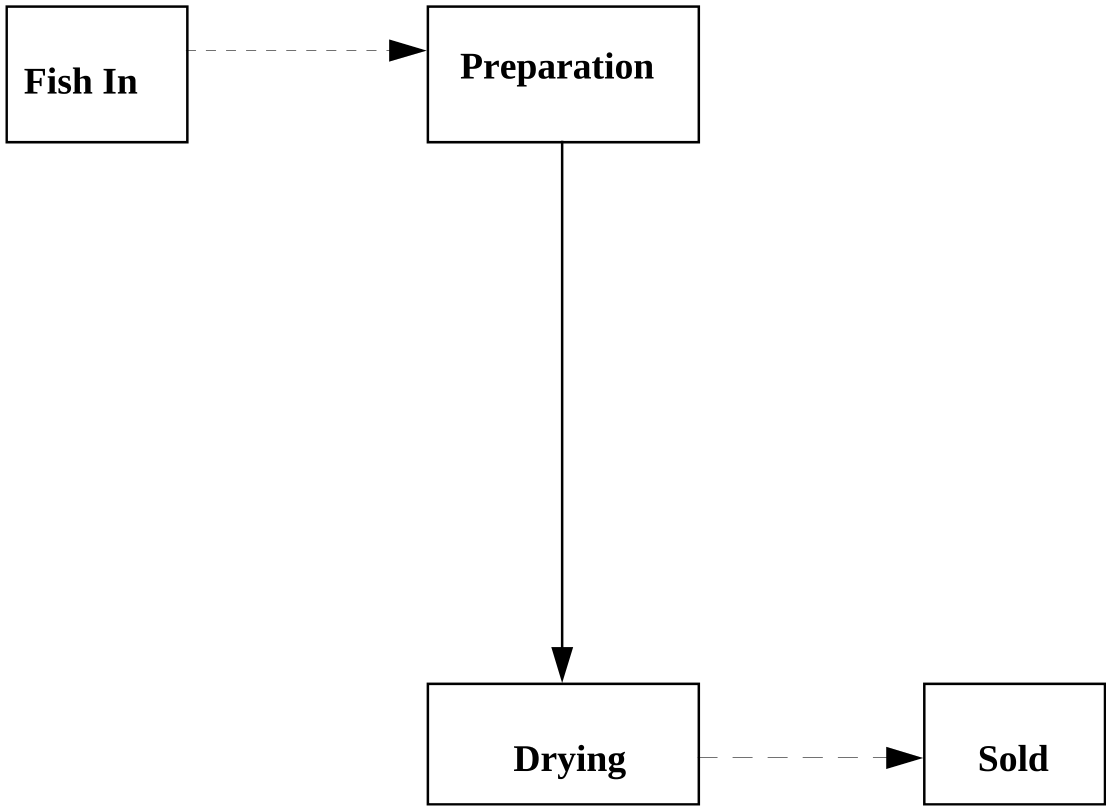
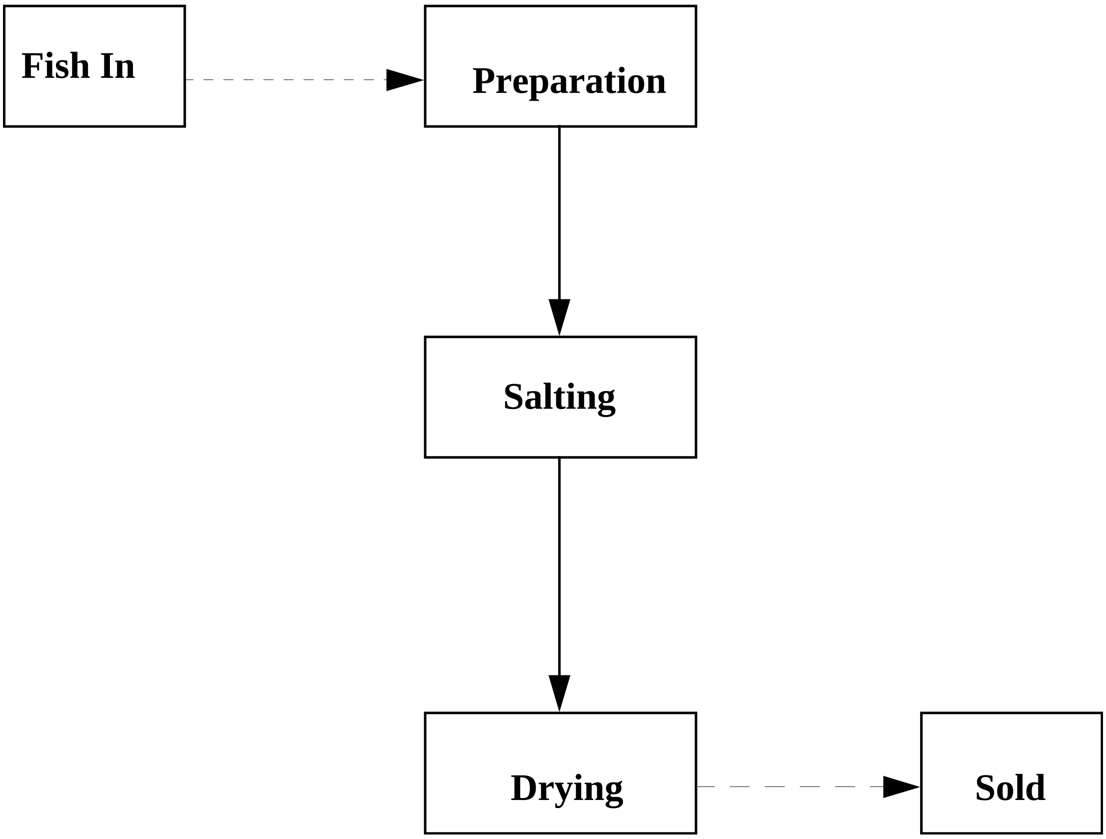
APPENDIX

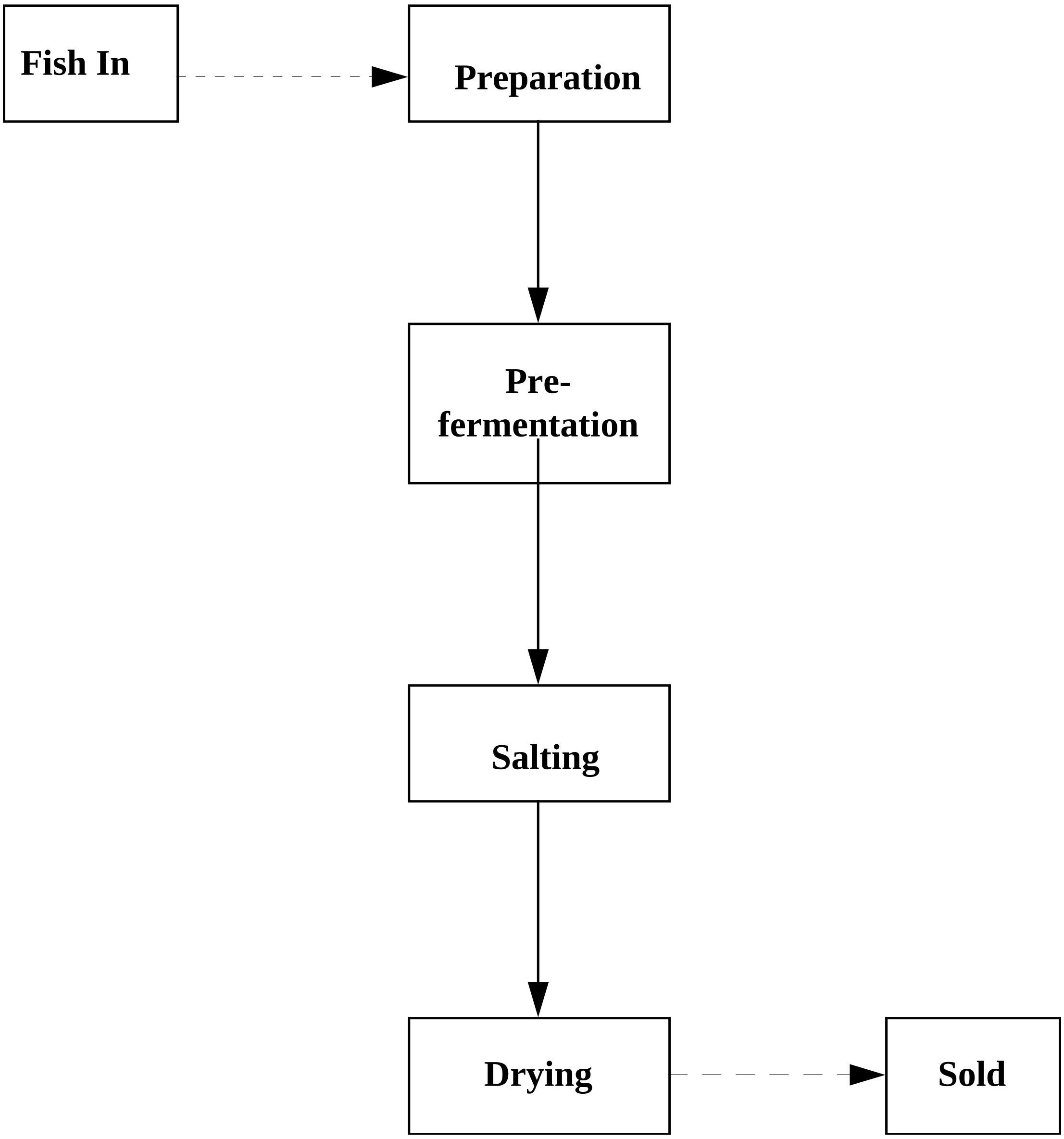
TEMPLATE FLOW DIAGRAM OF FISH PROCESSING BY SUN-DRYING ALONE



TEMPLATE FLOW DIAGRAM OF FISH PROCESSING BY SALTING AND SUN-DRYING



TEMPLATE FLOW DIAGRAM OF FISH PROCESSING BY PRE-FERMENTATION, SALTING AND SUN-DRYING



TEMPLATE FLOW DIAGRAM OF POSSIBLE PREPARATION STAGES

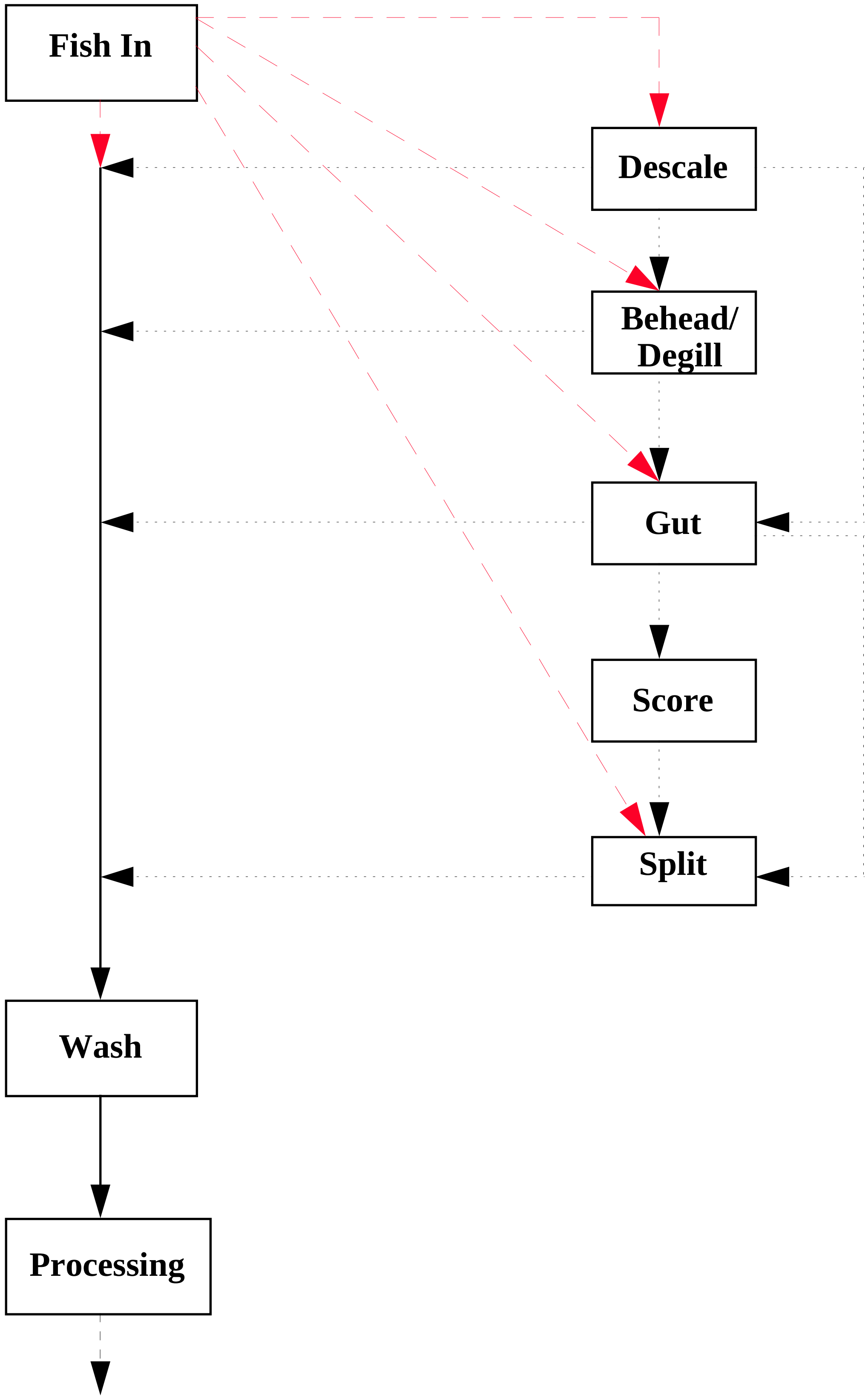


TABLE 1: IDENTIFIED RISK FACTORS AND APPROPRIATE METHODS OF CONTROL

RISK FACTOR	BRIEF EXPLANATION	APPROPRIATE CONTROL MEASURES
Raw Fish Quality	1. Partially spoiled fish is highly attractive to gravid female blowflies due to the liberation of blowfly attractant compounds by spoilage micro-organisms. 2. Poor and unhygienic handling practices cause further spoilage through the transfer of micro-organisms.	1. a) hold fish in ice and process ASAP b) where possible, only process fresh fish c) if spoiled fish must be processed, grade the fish for freshness then separate each grade during processing. 2. a) always follow good hygienic practices. Wash hands and knives regularly, and stack fish on clean surfaces, raised off the floor.
Preparation Steps	1. The mouth, eyes and gills are important sites for oviposition. These are thus important routes of direct infestation.	1. a) behead or de-gill fish early in the preparation b) if beheading/de-gilling is not possible, either; • heavily salt the gills, mouth and eye sockets with salt crystals • provide physical protection for the fish throughout processing (e.g. fly-proof boxes and salting tanks, netting over drying racks) • physically remove all eggs and hatching larvae present.

Preparation Steps cont.	2. The metabolic activity of anaerobes, present in the intestinal tract of the fish, liberates blowfly attractant compounds.	2. a) all fish should be gutted ASAP after capture b) if this is not possible, provide physical protection for the fish throughout processing (e.g. fly-proof boxes and salting tanks, netting over drying racks).
	3. The rate of moisture loss in fish processed without splitting is significantly reduced, extending the period in which the fish is attractive to gravid females and feeding larvae. Salt penetration into the flesh of whole fish is also retarded, thereby minimising any repelling effect the salt may otherwise exert.	3. a) all but very small species of fish should be split before salting or sun-drying. Care should be taken to ensure that surfaces exposed as a result of splitting are smooth, to prevent water from being trapped in any crevices, and to avoid providing sheltered oviposition and feeding sites for blowflies.
	4. Although large fish should be scored to increase the surface area for salt penetration and moisture loss, the resulting crevices provide a protected environment for oviposition, egg development and larval feeding.	4. a) during sun-drying, scores should be physically held apart with twigs to facilitate rapid drying b) layering salt crystals within the crevices may deter gravid females from ovipositing and may cause any eggs or larvae present to desiccate c) if the fish still appears to be at risk of infestation, screens or netting should be erected during sun-drying.

Pre- fermentation	1. During pre-fermentation, colonizing anaerobes liberate blowfly attractant compounds, making the fish highly attractive to gravid females.	1. a) fermentation tanks should be fitted with either fly-proof lids, or covered with fly-proof netting. If netting is used, a minimum gap of 2cm must be left between the top layer of fish, and the netting. b) during subsequent salting and/or sun-drying, physical protection in the form of insect-proof salting tanks and screened or netted drying racks should be provided.
	2. Indirect infestation can occur if any fish are infested prior to being placed in the fermentation tank. Larvae will readily move between adjacent fish in the tank.	2. inspect all fish prior to pre-fermenting. Any which are found to be infested should either; • have the eggs and larvae manually removed • be thoroughly washed under clean running water to wash off any eggs or larvae present • avoid the pre-fermentation stage, and try to minimise the level of infestation by applying large amounts of salt to the infested areas. This measure will not be effective if larvae have already burrowed into the flesh • processed separately from non-infested fish and losses in these fish accepted.

Salting	1. Gravid females are attracted to fish during early salting, and will readily oviposit on any exposed fish. Blowflies have even been recorded ovipositing on salt crystals covering fish, and on fish immersed in saturated brine.	1. a) fly-proof lids should be fitted to all sating tanks, and, wherever possible, all fish should be salted in tanks b) fish can also be dry salted in clean fly-proof boxes c) if tanks or boxes are not available for dry salting, netting should be erected over the stacks of fish to prevent blowflies from gaining access c) where netting can not be erected, the stack of fish can be carefully enclosed in clean plastic sheeting
	2. Indirect infestation can occur if any fish are infested prior to salting. Larvae will readily move between adjacent fish in dry stacks, pickles and brines.	2. inspect all fish prior to pre-fermenting. Any which are found to be infested should either; • have the eggs and larvae manually removed • be thoroughly washed under clean running water to wash off any eggs or larvae present • try to minimise the level of infestation by applying large amounts of salt to the infested areas. This measure will not be effective if larvae have already burrowed into the flesh • processed separately from non-infested fish and losses in these fish accepted.

Salting continued	3. Fish salted in stacks on the ground are, in addition, susceptible to indirect infestation through larvae, feeding on organic debris on the ground, moving onto the fish. **N.B.** Salting is only effective as a blowfly control method when: • the salt content of the fish flesh is greater than around 8% w.w.b. • salt penetration into the flesh is complete, and the salt is equally distributed throughout the flesh • any larvae infesting the fish remain in their first instar of development • the blowfly species present at the processing site are not salt-tolerant.	3. a)wherever possible, fish should be salted in tanks fitted with fly-proof lids or in clean fly-proof boxes b) if tanks are not available, fish can be dry salted on a raised platform, constructed out of an open material such as wire netting or bamboo poles for easy cleaning. c) when fish can only be salted on the ground, clean sheeting should be spread beneath the stack and the edges turned up around the side of the stack to limit the risk of larvae crawling onto the sheeting and thus onto the fish.

Drying	1. Fish is highly susceptible to attack by gravid females during drying as it is largely unprotected.	1. a) fly-proof netting should be erected over areas where fish are to be dried. b) if the level of oviposition is not high, eggs can be manually removed from the fish c) applying large amounts of salt to areas where eggs are likely to be deposited may deter oviposition
	2. Fish is predominantly attacked whilst the moisture content is high, therefore anyway of accelerating the rate of moisture loss is beneficial in reducing the level of infestation incurred.	2. a) whenever possible, fish should be dried on raised racks constructed of an open material which will allow air to circulate beneath the fish b) turn fish regularly to increase the rate of moisture loss from the underside of the fish c) where fish must be dried upon the ground, clean concrete is the most suitable surface d) never dry fish upon sand or loose earth as larvae can burrow into the ground in such areas to escape the intensity of the sun, and to pupate, thus sustaining the blowfly population at a site.

Drying continued	3. Fish which is case hardened may support larval feeding for an extended period as the moisture content of the inner tissues of the fish will remain high.	3. a) when the rate of drying is exceptionally high, move fish into the shade to avoid case-hardening.
	4. Fish is equally susceptible to indirect infestation throughout drying. This may result from: • larvae moving between adjacent fish • larvae present on the ground moving onto fish dried on the ground • larvae hiding upon drying racks or trays moving onto fresh batches of fish.	4. a) fish should never be overlapped during drying b) infested fish should be discarded or dried away from the other fish c) drying fish on trays supported on raised racks will reduce the risk of indirect infestation. Trays should be made of an open material such as chicken wire, fishing net, or, if necessary split bamboo carefully spaced apart d) ensure the surface on which the fish are to be dried is free of larvae and debris containing eggs or larvae.

Rainy Season	1. The extended drying time makes the fish attractive to gravid females and feeding larvae for longer.	1. a) protection from blowflies is probably necessary throughout the rainy season. Physical control measures (e.g. fly-proof nets, fly-proof boxes for holding and salting) are the most effective and safest methods of control. b)where fish is dried without protection, egg batches and feeding packs should be removed at least twice a day.
	2. Eggs are less susceptible to desiccation and so the problem is compounded.	2. a) applying salt to egg batches may cause desiccation of hatching larvae, but this will be dependent upon the salt staying in its crystalline from c) where fish is dried without protection, egg batches and feeding packs should be removed at least twice a day.
	3. Fish which is repeatedly rained upon will spoil, making it much more attractive to gravid females.	3. a) always cover fish during rainfall b) discard any fish which are spoiled, or, if they must be processed keep them far away from the other fish.

Environmental Conditions	1. High relative humidity causes a reduction in the drying rate of the fish, and so it remains attractive to gravid females and feeding larvae for longer. 2. Some species of blowfly have been shown to exhibit bimodal activity patterns, with activity decreasing during the middle of the day when the intensity of the sun is highest. The timing of oviposition follows this bimodality with eggs being laid predominantly in the late afternoon, but also in the early morning.	1. a) control measures to be followed are the same as for the rainy season. 2. a) Infestation may be reduced by placing fish out to dry at times of lowest blowfly activity. b) If fish are dried when blowfly activity is high, physical protection can be provided for the times when the fish is most at risk of attack.
Hygiene	1. Blowflies are attracted to and breed in areas of poor hygiene and sanitation. Processing sites where hygiene practices are poor therefore support higher blowfly populations, thus increasing the likelihood that the fish will become infested. 2. Fish waste discarded beneath processing tables is the principal from of organic debris at most sites. This material provides an ideal breeding and pupation site for blowflies.	1. a) processing sites should be kept clear of all rubbish, in particular organic waste. waste can be disposed of away from the site by burning or burying. 2. a) all fish waste should be collected and disposed of away from the site (see above) b) in some areas, there may be a market for the fish waste for conversion into poultry feed or fertiliser.

Table of Contents