# THE BENEFITS OF THE HAZARD ANALYSIS CRITICAL CONTROL POINT (HACCP) SYSTEM IN THE FISHING INDUSTRY

by

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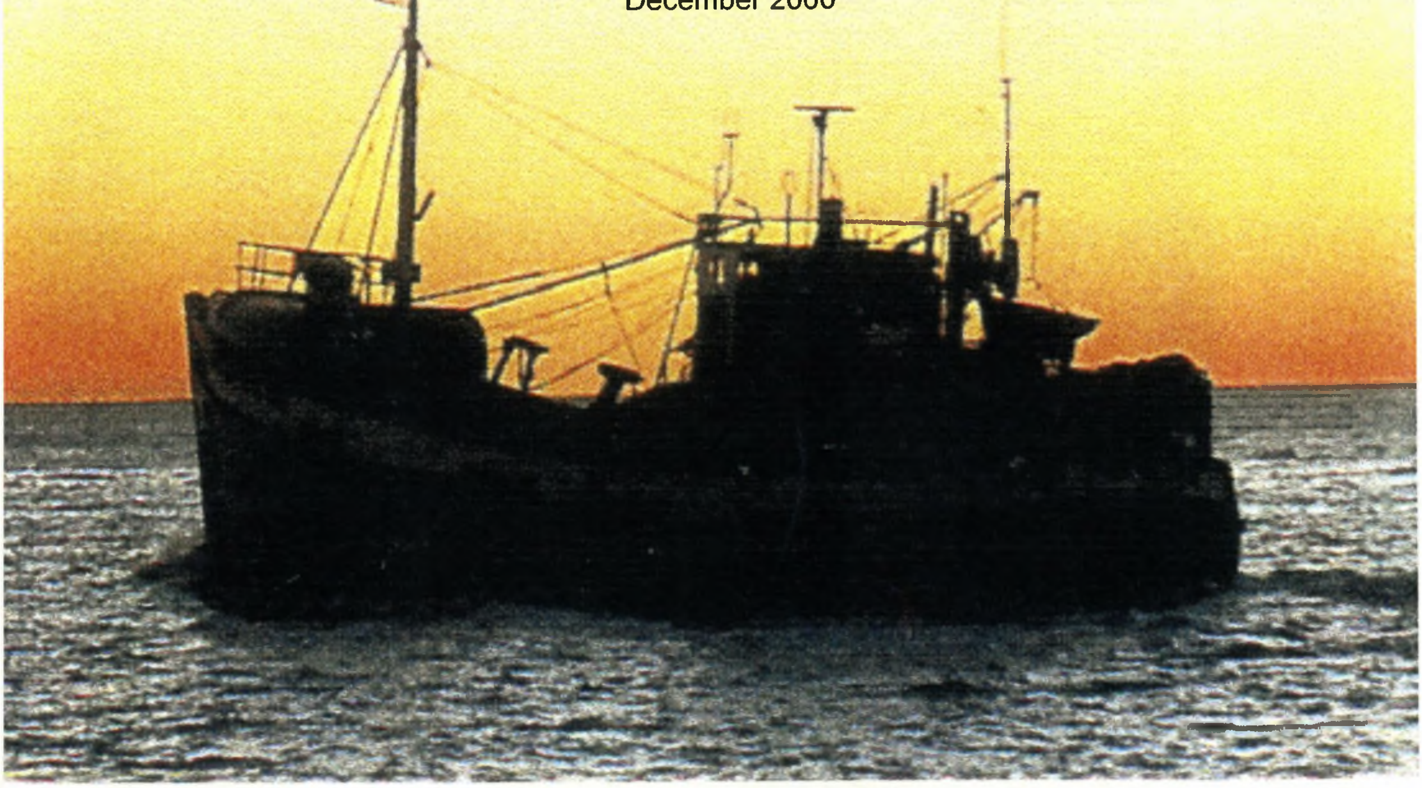

## Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any other university for a degree.

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Date

## Abstract

International food trade is steadily increasing, as is the global incidence of foodborne diseases. For this reason, governments require that food safety is managed formally and pro-actively within and across the borders of countries. The HACCP system has been proven over the years to be a system, which successfully manages food safety and is fast becoming mandatory in most developed countries. Procedures are also in place to enforce HACCP implementation in South Africa in the near future. The system is preventative in nature and focuses resources on areas, which are critical to food safety, thereby being practical and effective.

HACCP has always been and is currently very prominent in the international and local seafood industry. Moreover, South African fish processing companies cannot export their products to most international markets without implementing HACCP.

The fish species which are most caught and economically the most valuable in South Africa are the Cape hake (*Merluccius capensis* and *Merluccius paradoxus*) and the South African pilchard (*Sardinops sagax*). This study focussed on applying HACCP principles to these species. HACCP models were developed for a South African pilchard canning operation and a fresh Cape hake processing operation according to the seven principles recommended by the Codex Alimentarius commission.

The study showed how the storage of the catch in boat holds was proven to be a critical control point. The hazard was proven to be histamine poisoning due to the fact that boat holds were not cleaned adequately. Histamine-producing bacteria could grow on dirty surfaces and contaminate the catch with the toxin histamine, which could not be destroyed by subsequent canning processes. Viable contact plate counts and histamine-producing bacteria counts were performed. Results showed high counts in both instances, which validates that the point of hold cleaning is a CCP (Critical Control Point). Control measures were implemented in the form of a master cleaning schedule. Viable contact plate counts and histamine producing bacteria counts were repeated after the master cleaning schedule had been implemented. Counts decreased significantly in both instances, which validates the efficacy of the control measures. Ecologically justified, achievable target levels were calculated for viable contact plate counts and histamine-producing bacteria counts, which in future could be used in the HACCP plan of the case study company.

The study also showed how a HACCP verification study was conducted on a fresh Cape hake processing operation, in order to illustrate the concept of verification. Microbial growth due to poor temperature control was selected as the hazard. The verification performed was to log times and temperatures during processing, and to ascertain whether temperature control was adequate to prevent the hazard. Logging took place during all stages of processing from catching and holding in the on-board stocker pond, through to selling on a fish market in Vitoria, Spain. Results of the study

showed that the fish was reduced to below the critical limit of 3°C within 6 h and that it was kept under the critical limit during all stages of the process. This verifies that the hazard of microbial growth is controlled adequately.

This study may be used as a guideline to implement HACCP in a fish processing operation. The hard work, however, lies in customising and streamlining the system for each individual company. In order to achieve this, commitment should be available from top management and the system should be accepted and understood by all employees of the company. HACCP is also dependant on pre-requisite systems such as GMP, which should be in place before the system can work adequately. It is, furthermore, important that HACCP is practiced by all sectors of food processing from farm to fork.

The South African fishing industry carries the responsibility of leading the way and showing the rest of the food processing industry how HACCP should be implemented. Being South Africa's ambassadors in the international food safety arena, it is crucial for the sake of future exports and economic growth that HACCP is implemented and functioning in this area.

# Uittreksel

Internasionale handel in voedsel is aan die toeneem en dit gaan ook gepaard met 'n toename in siektes afkomstig van voedselinname. Dit het veroorsaak dat regerings besig is om streng vereistes rondom voedselveiligheid te stel wat betref plaaslike vervaardiging, asook in- en uitvoer van voedsel. Die HACCP-sisteem is bewys oor die jare as 'n sisteem wat suksesvol die veiligheid van voedsel kan beheer en is tans vinnig besig om verpligtend te raak in meeste ontwikkelde lande. Selfs in Suid-Afrika is daar al maatreëls in plek om HACCP in die toekoms te verplig. HACCP is 'n voorkomende sisteem wat hulpbronne fokus op areas wat krities is vir voedselveiligheid.

HACCP was, en is steeds baie prominent in die internasionale en plaaslike visindustrie. Die situasie in die land is tans van so aard dat plaaslike visverwerkingsmaatskapye hulle produkte kan uitvoer, alvorens hulle HACCP geïmplementeer het nie.

Die twee vis spesies wat in die land, in die grootste volume verwerk word en wat gevolglik ekonomies die meeste werd is, is Kaapse stokvis (*Merluccius capensis* en *Merluccius paradoxus*) en die Suid-Afrikaanse sardyn (*Sardinops sagax*). Hierdie studie het gefokus op die implementering van HACCP beginsels op hierdie twee spesies. HACCP modelle is ontwikkel vir 'n Suid-Afrikaanse sardyn inmaak bedryf, asook vir 'n vars Kaapse stokvis bedryf wat gebaseer is die sewe HACCP beginsels, soos aanbeveel deur die Codex Alimentarius Kommissie.

In die studie word daar bewys dat die opberging van die vangs in bootruime 'n kritiese punt is. Die gevaar wat gevolglik geïdentifiseer is, was histamien vergiftiging as gevolg van die feit dat bootruime nie behoorlik skoongemaak word nie. Histamien-vormende bakterieë kan groei op die vuil oppervlaktes en die vangs kontamineer met histamien toksiene. Hierdie toksiene is hittebestand en word nie vernietig tydens daaropvolgende verwerkingstappe nie. Lewensvatbare kontakplaat tellings en histamien-vormende bakterieë tellings is uitgevoer op bootruim oppervlaktes. Resultate van albei toetse het hoë tellings gewys, wat bewys dat die stap krities is. Beheermaatreëls is geïmplementeer in die vorm van 'n skoonmaak skedule. Lewensvatbare kontakplaat tellings en histamien-vormende bakterieë tellings is herhaal, nadat die skoonmaak skedule geïmplementeer is. Tellings was beduidend laer, wat bewys dat die beheermaatreëls effektief was. Ekologies bewese, haalbare teikenvlakke is bereken vir kontakplaat tellings en histamien vormende bakterieë tellings, wat gebruik is in die HACCP plan van die gevalle studie maatskappy.

Die studie het ook gehandel oor hoe 'n HACCP verifikasie studie uitgevoer is op 'n Kaapse stokvis verwerkingsbedryf, sodat die verifikasie konsep verduidelik kon word. Mikrobiologiese groei as gevolg van swak temperatuurbeheer is gekies as die gevaar. Tyd-temperatuur opnames is geneem om te verifieër of beheermaatreëls genoegsaam was om die gevaar te verhoed. Die opname het alle prosesseringsstappe ingesluit

vanaf vangs en berging van vis regdeur totdat dit verkoop is op 'n vismark in Vitoria, Spanje. Resultate het gewys dat die temperatuur deurgaans benede die kritiese limiet van 3°C in 6 ure gebly het. Dus verifieër dit dat die gevaar van mikrobiologiese groei voldoende beheer word.

Hierdie studie kan gebruik word as 'n riglyn om HACCP te implementeer in 'n visverwerkingsbedryf. Die harde werk lê egter in die toepassing en verfyning daarvan vir elke individuele maatskappy. Hierdie taak is slegs die verantwoordelikheid van die maatskappy self. Toewyding van topbestuur en aanvaarding vanaf alle werknemers is noodsaaklik om dit te kan bereik. HACCP is ook afhanklik van ondersteunende stelsels soos goeie vervaardigingspraktyke (GMP), alvorens dit sal werk. Verder is dit nodig dat HACCP toegepas word in alle sektore van die voedsel ketting vanaf primêre produksie totdat die produk deur die verbruiker geëet word.

Visverwekingsmaatskapye internasionaal en plaaslik was onder die eerste industrieë wat HACCP geïmplementeer het. Omdat hulle Suid-Afrika se ambassadeurs in die internasionale voedselveiligheidsarena is, is dit is krities in terme van ekonomiese groei, dat HACCP geïmplimenteer word en werk in die industrie.

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**Contents**



Language and style used in this thesis are in accordance with the requirements of the *International Journal of Food Science and Technology*. This thesis represents a compilation of manuscripts where each chapter is an individual entity and some repetition between chapters has, therefore, been unavoidable.

# CHAPTER 1

# INTRODUCTION

Whenever one steps on to an aeroplane, one cannot avoid considering the risks associated with flying. Thoughts of mechanical failure, pilot error and terrorists fill one's mind. The moment the aircraft takes off, one is resigned to fate, placing faith in the systems used by the airline to ensure one's safety. The same is true of surgery. Thoughts of mortality are difficult to avoid when facing the surgeon's knife. Faith in the efficiency of the hospital's systems helps to convince that there is little need for worry. In the consumption of food however, few of us consider the risks associated with food. We make assumptions that foods are processed and prepared by people who know about food, that they are as qualified and highly trained for their jobs as are pilots and surgeons. We assume that there are systems in place. Can we be sure? (Early, 1995).

International food trade is steadily increasing, bringing important social and economic benefits to the world's population. In other words people can now enjoy a wider variety of foods at more affordable prices (FAO & WHO, 1997). This trade is currently expected to be in excess of US$ 500 million per annum (Rajasekar, 2000). However, the growth in food trade is also associated with a growth in the number of food borne illnesses, food borne injuries and food spoilage. Such incidences may have human health as well as economic consequences (FAO & WHO, 1997).

The global incidence of food borne illnesses is difficult to estimate, but it has been reported that in 1998 alone 2.2 million people, including 1.8 million children, died from diarrhoeal diseases (WHO, 2000). A great proportion of these cases are food safety related. In industrialised countries, the percentage of people suffering from food borne diseases each year has been reported to be up to 30% of the population. In the United States (USA), for example, approximately 76 million cases of food borne diseases, resulting in 325 000 hospitalisations and 5 000 deaths, are estimated to occur each year (WHO, 2000). In South Africa, food safety incidences are not well documented, but are continually on the increase (Pretorius, 1998).

The reason for the increase in food safety incidences can be attributed to the processing techniques, essential for providing food for the rapidly expanding human population (Cloete, 1996). Other particular reasons listed are: innovations in packaging; improved formulation and distribution systems; high-speed automation; and minimal processing of foods. The continuous emerging of new pathogens and the lack of expertise and training in the food industry have also been associated with the increase in incidences (Bauman, 1994). Furthermore, public interest in food safety is changing. Consumers are becoming more aware of food safety issues and are demanding higher safety assurances from governments (Rajasekar, 2000).

It is, therefore, in the interest of all food producers, manufacturers, distributors, retailers and regulators to formally manage food safety. HACCP (Hazard Analysis Critical Control Point) is a proven system, which can be used to manage food safety (FAO & WHO, 1997).

The HACCP concept was pioneered in the early 1960's, in an effort to develop safe foods for astronauts during the United States space programme. HACCP subsequently evolved into the rest of the food industry and became mandatory in certain countries during the 1990's (Bauman, 1995). Currently, the Codex Alimentarius Commision of the joint Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO), recommends the use of HACCP as a tool to manage food safety (FAO & WHO, 1997). In South Africa, HACCP is in the process of becoming mandatory. The Department of Health has published the first draft regulation concerning the use of HACCP (Pretorius, 1998).

HACCP can be described as a preventative system of food safety control, focussing resources on critical areas in the production process (Leaper, 1992). Generally, seven principles are used to describe the mechanism of HACCP. These range from conducting a hazard analysis and identifying critical control points (CCPs), to establishing target levels, tolerances and defining monitoring, corrective action and verification procedures (Bauman, 1994; FAO & WHO, 1997; Huss, 1994; Leaper, 1992; SABS, 1999). In order for HACCP to function adequately it has to be underpinned by pre-requisite programmes such as Good Manufacturing Practices (GMP) (SABS, 1999). If HACCP is implemented before GMP, it will lead to too many critical control points, which, in turn, may influence the practicality and economic viability of the system (Mitchell, 1992).

Since its development, HACCP has been very prominent in the international seafood arena (Bauman, 1995). This can be attributed to the fact that seafood is a high risk food item in terms of food safety (Billy, 1994). It has also been reported that there is increasing consumer concern and a public perception that seafood is unsafe and this will in the future require more regulation and inspection (Garrett & Hudak-Roos, 1990). The reasons for the use of HACCP in seafood industries is not only safety related. HACCP is used as a political tool by some countries, to create a trade barrier which will prevent inexpensive seafood entering their country and disturbing the market (Uys, 1999).

In South Africa, HACCP became mandatory for seafood export to EU countries in December 1995 and to the USA in December 1997. South African seafood processors can, therefore, currently not export their product to these countries without operating under HACCP controls (SABS, 1999).

The two largest sectors in South Africa's commercial fishing industry are the demersal and pelagic industries. The demersal industry generated an income of R 1104 M and the pelagic R 439 M in terms of wholesale processed value in 1997. Demersal means the fish species which are trawled (deepwater, midwater and inshore) or longlined and are processed and mostly sold fresh or frozen. Cape hake (*Merluccius capensis* and *Merluccius paradoxus*) is by far the largest constituent of this sector. Pelagic species are normally caught by purse seining and are canned or made into fishmeal, fish oil or bait. The main pelagic species is the South African pilchard (*Sardinops sagax*) (Stuttaford, 1999). It is, therefore, in South Africa's economic interest that these two industries are completely familiar with the HACCP system.

A critical element in a food safety system should be a strong science base to underpin decision-making (Henney, 2000). Unfortunately, very little food safety or science is documented in this regard for the South African fishing industry. Experience has shown that there tends to be a definite lack of science and, consequently, understanding of HACCP (Venneman, 1998). Specific areas where fish processors lack understanding, is to correctly select, validate and verify CCPs (Raschke, 1997), as well as to set ecologically justified critical limits to monitor these CCPs (Cloete, 1996). A further tendency is also to under-control critical control points in HACCP studies (Henney, 2000). Based on these limitations, the principal aim of this study was to provide guidance to the South African fishing industry in developing scientifically correct HACCP based food safety systems. Specific project objectives were:

- To develop HACCP models for Cape hake and South African pilchard, two of the country's commercially most important seafood products;
- To select a processing step in one of the above studies and validate whether the point is critical;
- To show how this CCP can effectively be controlled and to use the data to set scientifically correct critical limits; and
- To conduct a HACCP verification study on one of the above processes, in order to illustrate the concept of verification.

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# CHAPTER 2

# LITERATURE REVIEW

## A. The concept and evolution of HACCP

Hazard Analysis Critical Control Point (HACCP) is as its name suggests, a system where hazards are analysed and controlled at critical control points. The system is intended for the food industry and is preventative in nature (Bauman, 1994). Formally, HACCP is defined as a system, which identifies, evaluates and controls hazards, which are significant for food safety (FAO & WHO, 1997; SABS, 1999). HACCP basically identifies what may go wrong (in terms of food safety), how, where and when (Leaper, 1992).

The HACCP system of food safety was pioneered in 1960 by The Pillsbury Company, the U.S. Army Natick Research and Development Laboratories, and the National Aeronautics and Space Administration (NASA) in their collaborative development of foods for the space programme (Bauman, 1995; Mortimore & Wallace, 1998; Vail, 1994). The project team recognised the potential disaster presented by the illness of an astronaut in space. Moreover, the food products that were being produced for space use should not be contaminated which might result in a failed or even catastrophic mission (Bauman, 1994). Among the illnesses astronauts could be susceptible to, were those associated with their food supply. It should be kept in mind that these foods were designed to be used during orbital and lunar missions requiring many days in space. These foods were highly processed and preserved and, therefore, associated with many potential food safety risks (Sperber, 1991). Although microbiological illnesses were the primary concern, other issues such as metal, glass, and chemical adulteration were included as potential food-borne dangers to their health (Bauman, 1994).

Food safety can not be verified solely by end product testing. Therefore, it was necessary to design the production process so that the elimination of potential hazards could be assured. In other words, safety had to be built into the production process (Sperber, 1991) and this had to start as early in the process as possible (Bauman, 1995). Using this approach, the HACCP concept for food safety was developed (Leaper, 1992).

Pillsbury presented the HACCP concept publicly at the first Conference for Food Protection in 1971 (Archer, 1990; Sperber, 1991). HACCP principles were incorporated into the low acid canned foods regulations of the United States Food and Drug Administration (USFDA) in 1974 (Sperber, 1991). In the 1970's and early 1980's, the HACCP approach was adopted by other major food companies and began to receive attention from various sectors of the food industry (Bigalke & Busta, 1982). In 1985, the National Academy of Sciences (NAS) in the USA recommended that the HACCP approach be adopted by regulatory agencies (Mortimore & Wallace, 1998; Sperber, 1991). From here the system was promulgated by regulating agencies in the United States, adopted by segments of the food industry and offered to all who recognised its value (Bauman, 1995). In 1992, it became mandatory for the Canadian seafood industry to use a HACCP based Quality Management Plan (QMP)(McEachern & McGuiness, 1992; Melanson, 1994). Meanwhile in Europe, the European Economic Council (EEC) strongly recommended the use of HACCP by food businesses to meet the requirements of the legislation. In 1993, HACCP principles were formally included in EEC Directives (Mortimore & Wallace, 1998).

Since the early days of HACCP, there has been a general, common understanding of its principles. However, there existed a need for an internationally accepted, uniform HACCP guideline. The Codex Alimentarius Commision (CAC) accepted the role of compiling such a guideline. The CAC was formed in 1962 as a joint effort by the Food and Agriculture Organisation (FAO) and the World Health Organisation (WHO). Their mandate was to protect the health of the consumer and to promote fair practices in trade (Rajasekar, 2000). Formal HACCP principles were published by the CAC in 1993 (revised in 1997) under the title: "The HACCP system and guidelines for its application". Today many countries including South Africa, are adopting these principles in their own regulations (Pretorius, 1998).

## B. HACCP in South Africa

South Africa effectively returned to the global food trading community in 1994 as a result of internal political changes. The responsible authority for ensuring the safety of the food produced and processed in South Africa is the Directorate Food Control of the Department of Health. This body realised that an urgent need existed for steps to be taken, to ensure that South Africa's food control system was on an equivalent level with that of at least its major food trading partners. A critical aspect in this regard was that standards relating to the composition and handling of food was established and regulated through the legislative process of the country. It was, therefore, imminent that South Africa had to introduce measures, which would ensure that the HACCP approach becomes part and parcel of the future food control system of the country. It was also important that South Africa's HACCP approach was in line with the guidelines published by CAC (Pretorius, 1998).

In February 1997, a specialist working group was established to attend to the formulation of draft HACCP regulations. This working group was a subsidiary of the Food Legislation Advisory Group (FLAG), a non-statutory, multi-disciplinary and sectoral forum established by the Directorate Food Control to advise the Department of Health on food safety related legislation. The working group was nominated by the consumer bodies, academic and research institutions and consisted of approximately 25 members (Pretorius, 1998).

In June 1998, a draft HACCP regulation was proposed by the working group and was subsequently accepted by FLAG. Further remaining phases in the process are: techno-legal preparation, ministerial approval and publication in the South African

Government Gazette. These HACCP draft regulations will then be implemented in one industry at a time until the entire local food processing Industry has been covered (Pretorius 1998). The present status therefore at the moment is that formal HACCP systems are not currently mandatory in South Africa but long-term implementation steps are in place.

## C. The implementation of HACCP

Prior to the application of HACCP in a food processing operation, basic principles of food hygiene found in codes of Good Manufacturing Practices (GMP) should first be applied (FAO & WHO, 1997; Mitchell, 1992). Moreover, the HACCP system cannot function in isolation and should be underpinned by GMP in order to function effectively (SABS, 1999; Mortimore & Wallace, 1998). Good Manufacturing Practices can be defined as the combination of manufacturing and quality procedures aimed at ensuring that a product is consistently manufactured to its specification (SABS, 1999). Good Manufacturing Practices includes aspects such as: employee and plant hygiene practices; food handling practices; as well as plant and equipment design (Goodfellow, 1995). It is extremely important to realise that if HACCP is implemented before GMP is in place, this will lead to too many critical control points, which, in turn, may influence the practicality and economic viability of the system (Mitchell, 1992).

The South African responsible authorities have incorporated GMP principles into its legislation. The following should, therefore, be understood and functioning in South African food companies, before HACCP is attempted: the Health Act of 1977 (Act 63 of 1977), which controls the premises on which food is produced (Anon, 1977); and the Foodstuffs, Cosmetics and Disinfectants Act of 1972 (Act 54 of 1972), which controls the manufacture, importation and sale of foodstuffs (Anon, 1972).

Once GMP is in place the actual HACCP implementation process can start. The main steps in a HACCP program are to firstly identify and assess potential microbial, chemical and physical hazards associated with a food operation. The next step is to identify which points in the process are critical in terms of food safety (Bauman, 1995; Mitchell, 1992; Stevenson, 1990). Worldwide, the implementation of a HACCP system is generally explained under seven principles (FAO & WHO, 1997):

PRINCIPLE 1: Conduct a hazard analysis. Prepare a flow diagram of the steps in the process. Identify and list the hazards and specify the control measures;

PRINCIPLE 2: Identify the Critical Control Points (CCPs) in the process;

PRINCIPLE 3: Establish target level(s) and tolerance(s), which must be met to ensure each CCP is under control;

PRINCIPLE 4: Establish a monitoring system to ensure control of the CCP by scheduled testing or observations;

PRINCIPLE 5: Establish the corrective action to be taken when monitoring indicates that a particular CCP is out of control;

PRINCIPLE 6: Establish documentation concerning all procedures and records appropriate to these principles and their application; and

PRINCIPLE 7: Establish verification procedures, which include appropriate supplementary tests, together with a review, which confirms that HACCP is working effectively.

The application of these seven HACCP principles can be logically applied in 12 stages as shown in Fig.1 (SABS, 1999 ; FAO & WHO, 1997). Each stage is discussed below:

*Stage 1: Select a HACCP team*

A multidisciplinary HACCP team consisting of personnel with knowledge of, and expertise on the specific product and process is selected (Mortimore & Wallace, 1998). Traditionally, only technical personnel are chosen for such teams. It is however, very important to also include non-technical personnel, so that non-technical factors such as shift work and operating procedures are included in the analysis (Mitchell, 1992). A typical HACCP team will consist of a team leader, a facilitator, and relevant specialists. The team leader (also sometimes referred to as a management representative), carries the responsibility of driving the HACCP effort (SABS, 1999). The facilitator is responsible for organising meetings, communicating progress and seeing that tasks are completed on time (SABS, 1999). Specialists, contributing specific skills may include : quality assurance personnel; quality controllers; production specialists; engineers; food technologists; microbiologists and buyers (Leaper, 1992).

*Stage 2: Describe product*

A full description of the product(s) in the HACCP study should be drawn up, and include relevant food safety information such as: composition; physical/chemical structure; microbiological characteristics; water activity; pH; packaging; storage conditions; method of distribution and usage instructions (FAO & WHO, 1997). Ideally, records should be kept of all raw material and end-product characteristics concerned in the HACCP study. This is also generally referred to as product specifications (FLAIR, 1994).

*Stage 3: Identify Intended Use*

The intended use means the normal use of the product by the end user or consumer. Its function is to focus attention on the likely uses or abuses of the product after it leaves the control of the food producer. It is this likely usage, that will determine some of the CCPs in the operation (Mitchell, 1992). This stage is very important in order to identify vulnerable target groups, e.g. young children or institutional feeding of the health impaired (FAO & WHO, 1997).

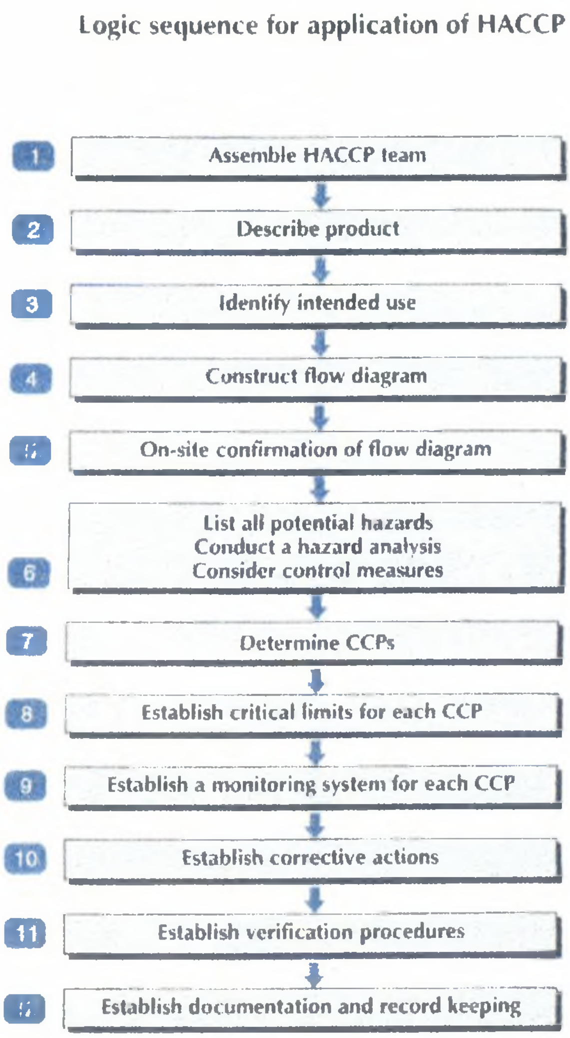


**Figure 1.** Logic sequence for application of HACCP (FAO & WHO, 1997).

*Stage 4: Construct a flow diagram*

The HACCP team should then define all the steps in the operation in a logical flow diagram (Mortimore & Wallace, 1998). The word "step" has a particular meaning in the context of HACCP: it refers not only to operations, processes or procedures, but also to raw materials (Mitchell, 1992). When applying HACCP to a given operation, consideration should be given to steps preceding and following the specified operation (FAO & WHO, 1997).

*Stage 5: On-site confirmation of the flow diagram*

The theoretical flow diagram should be validated on site, so as to ensure that the flow diagram and the data reflect an accurate presentation of the operation. The diagram should be amended to take into account any deviations from the original diagram (SABS,1999).

*Stage 6: List all potential hazards and possible control measures associated with each step*

Potential hazards that are reasonably likely to occur should be listed for each process step as per the flow diagram (Leaper, 1992). Hazards may be biological, chemical or physical of nature (Sperber, 1991). Control measures should then be considered, which can be applied to each hazard (SABS, 1999). A control measure is defined as any factor or activity, which can be used to prevent, eliminate or reduce to an acceptable level, a food safety hazard (Mortimore & Wallace, 1998). More than one control measure may be required to control a specific hazard and more than one hazard may be controlled by a specified control measure (FAO & WHO, 1997). Whilst conducting this stage, care must be taken to only include significant hazards. If insignificant food safety hazards are considered the HACCP study may become impractical and cumbersome (Mortimore & Wallace, 1998). A strong science base should always be used to underpin decision-making (Henney, 2000). Various risk assessment techniques are available to be used during hazard analysis (Early, 1995; Mortimore & Wallace, 1998; Nottermans, *et al.*, 1995; Harris *et al.*, 1995).

*Stage 7: Determine Critical Control Points*

Critical Control Points are selected. These are points, which if not controlled might result in an unacceptable health risk. It is within this principle that the dynamic nature of HACCP is most evident (Sperber, 1991). The determination of CCPs can be facilitated by the application of a decision tree as shown in Fig. 2, which indicates a logical reasoning approach. Although this tree is useful to explain the logic and depth of understanding needed to determine CCPs, it is not specific to all food operations. It should, therefore, be used in conjunction with professional judgement and modified where necessary (FAO & WHO, 1999).

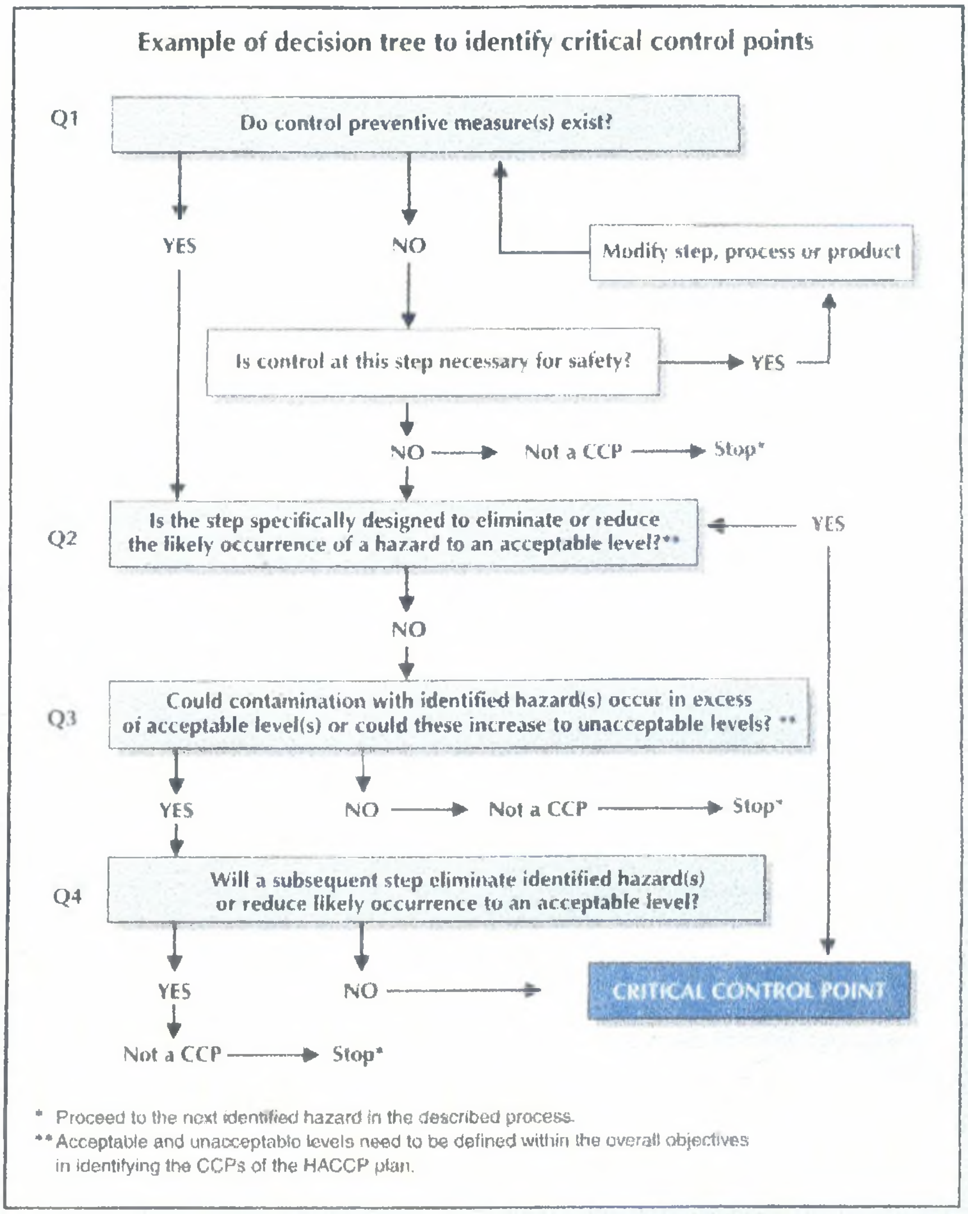


**Figure 2.** Decision tree to identify critical control points (CCPs) (FAO & WHO, 1997).

*Stage 8: Establish critical limits for each CCP*

In order to monitor the CCP, target levels and tolerances must be specified for each preventative measure. The exact limits required for each preventative measure to be effective should be specified for each CCP. Characteristics that can be measured quickly and easily are preferred (Mitchell, 1992). Examples of these include: assessments of temperature; time; moisture level; pH; water activity; available chlorine and organoleptical parameters, such as visual appearance and texture (SABS, 1999).

*Stage 9: Establish a monitoring system for each CCP*

Monitoring procedures should be defined clearly for each CCP. The monitoring system shall produce an accurate record of performance for future reference for purposes of verification (FAO & WHO, 1997). Monitoring is the measurement or observation at a CCP of the target level and tolerance set down for each preventative measure (Mitchell, 1992). When designing monitoring procedures, it is crucial to define exactly: who will act; when monitoring will take place; how monitoring will take place; and who will verify that monitoring has been done correctly (SABS, 1999)?

*Stage 10: Establish corrective actions*

Corrective action should be taken whenever a CCP has been found to deviate from the specified target levels and tolerances (FAO & WHO, 1997). The procedures must include actions to be taken to ensure that the CCP has been brought back within critical limits as well as actions to be taken to deal with defective products (FLAIR, 1994). Many HACCP systems have failed because corrective actions were not followed through adequately (Vail, 1994).

*Stage 11: Establish verification procedures*

The HACCP team should verify whether the HACCP system is functioning correctly (Mitchell, 1992). Examples of verification activities include: review of the HACCP system and records through audits; review of deviations and product dispositions; confirmation that CCPs are under control; and surveys from the marketplace (for example consumer feedback) for unexpected health or spoilage problems (FAO & WHO, 1997). Consumer feedback can often be an early warning that all may not be well in the HACCP system (Bauman, 1994).

*Stage 12: Establish documentation and record keeping*

Effective and accurate record keeping is essential to the application of a HACCP system. All HACCP procedures should be documented. Documentation and record keeping should be appropriate to the nature and size of the operation (FAO & WHO, 1997). Procedures should also be in place for the control of records. These include: identification; collection; indexing; accessing; filing; storage and disposition of all records generated. Such records could be generated during: HACCP studies; HACCP implementation; HACCP maintenance; tests and verification data; review and assessments or audits (SABS, 1999). Effectively, a HACCP manual should be compiled to document the HACCP study (Mitchell, 1992).

This 12-stage approach is very useful for companies who are starting HACCP from scratch. However, the question arises as how one implements HACCP in a company which is already operating under a recognised quality management system such as ISO 9000. Most companies find that the control programs already in place can with little modification be utilised directly (Bauman, 1991). In fact, the CAC HACCP code of practice may be successfully combined with IS0 9000 (Bauman, 1994). ISO 9000 is a series of standards, which includes the requirements of 20 clauses to be implemented. Each of the 20 clauses has relevance to HACCP, and in many instances, it is vital that HACCP is supported by such procedures. For the transition from ISO 9000 to HACCP, often the only aspect required is a HACCP policy manual, which highlights HACCP components in the ISO system. The 12-stage HACCP approach can be followed to compile such a manual but excess work will be saved since a great deal can be cross referenced to the ISO 9000 policy manual (Mortimore & Wallace, 1998).

## D. The benefits of HACCP

If HACCP is implemented correctly and is accepted understood and functioning correctly in a company, it may lead to a number of benefits. Resources such as personnel, raw materials and equipment will be better utilised because of formalised procedures and increased discipline (SABS, 1999). HACCP will lead to less product dispositions, rejections and failures because of built-in corrective action procedures (Bauman, 1994).

In case of failures, the HACCP system can aid in tracing ingredients and processes back to ascertain liability (Scarlett, 1991). Furthermore, HACCP recognises where the responsibility lies for producing safe food. Each participant in the food production system that adopts a HACCP plan accepts responsibility for producing safe food (Taylor, 1994).

Since the system is preventative in nature (Taylor, 1994), this will lead to a saving in end product testing. For example, consider the implication of when HACCP is applied to a fresh fruit packhouse and the presence of agricultural chemical residues are identified as a CCP. In such a case the implemented HACCP system shall call for a preventative control measure such as evaluating the spraying records of the farmer (type and frequency of chemical used) rather than relying on residual chemical testing of the end product. Not only is this method less expensive, it is also a lot more reliable. Likewise, by accurately monitoring the time/temperature profile of a batch of fish, it becomes unnecessary to conduct end-product microbial testing, since it is known that if the specified tolerances were met, there will be no significant microbial growth (Uys, 1999).

In short, by using HACCP, the prevention and appraisal costs (i.e. costs for training, calibration, and monitoring) of a food company might increase, but product and process failure costs will be reduced, resulting in an overall reduction in the cost of quality (Bigalke & Busta, 1982). HACCP will, therefore, lead to increased profits by food manufacturers which in turn will lead to a safer product for the consumer (Sperber, 1991). This will, in the long term, promote international trade by increasing confidence in food safety (SABS, 1999).

## E. HACCP and seafood

Worldwide consumers are turning to healthier, more natural foods. Many people are turning to seafood as an alternative to red meat. The low fat content of white fleshed demersal fish and the effects on coronary heart disease of the n-3 polyunsaturated fatty acids found in fatty pelagic fish, make this a better prospect than red meat. However, more people are also becoming poisoned by seafood (Huss, 1994). Of the reported cases of foodborne disease outbreaks in the United States between 1973 and 1987, seafood was the most frequently associated with disease (Huss,1994). Recently, the Center for Food Safety and Applied Nutrition in the United States stated that it still regards seafood safety as one of their top priorities (Henney, 2000).

The reasons for the high number of seafood borne diseases can be attributed to the fact that seafood has perhaps the most complex and diverse microbiology of any food commodity. Seafood is a disparate array of products encompassing literally hundreds of species, each with a different habitat and a different range of host micro-organisms, toxins, parasites, chemicals and other potential hazards that may affect food safety (Friedman, 1996). Seafood is still mostly caught wild and subject to a variety of both natural and man made hazards (Billy, 1994). Fish has to be harvested under difficult conditions and at varying distances. These conditions, distances and duration of fishing trips can tax any system of controls to ensure safety. Seafood is, therefore, undoubtedly the most perishable and most prone to food safety risks of all flesh foods (Friedman, 1996).

Consumers are becoming aware of the risk associated with seafood and are demanding stricter regulations and more stringent inspections (Garrett & Hudak-Roos, 1990). It is, therefore, not surprising that since the development of HACCP in the 1960's, seafood industries have played a prominent role in the evolution of HACCP (Bauman, 1995). In fact, HACCP had already been introduced into the seafood industry by the early 1970's. A significant contribution was made by Lee (1977), who applied HACCP principles and outlined HACCP for the seafood industry. He was the first to categorise seafood in terms of risks as is shown in Table 1. This table defines the hazard analysis 'rule of thumb' still used today (Garrett *et al.*, 1995). The HACCP concept was adopted for mandatory federal regulation in the United States for low acid canned seafood, mainly because of the threat of *Clostridium botulinum*. Throughout the 1980's, HACCP

**Table 1.** Seafood end-product hazard analysis (Garrett *et al.*, 1995).

| Category (Decreasing risk) | Description | Example |
|---|---|---|
| 1. | Heat-processed foods usually consumed without additional cooking | Cooked shrimp |
| 2. | Non-heat processes raw foods often consumed without additional cooking | Shucked molluscan shellfish eaten raw |
| 3. | Formulated foods usually consumed after cooking | Fish sticks and breaded shrimp |
| 4. | Non-heat processed raw foods usually consumed after cooking | Fresh or frozen fish fillets and cooked molluscan shellfish |
| 5. | Raw seafood usually consumed after cooking | Live crustacean and molluscan shellfish |

became a common term in the United States seafood industry and, in 1988, the American Congress mandated the National Oceanic and Atmospheric Administration to design a HACCP type surveillance program. HACCP became mandatory for the first time for an entire fishing industry in February 1992 in Canada and the Canadian fishing industry had to adopt a HACCP based Quality Management Plan (QMP) (McEachern & McGuiness, 1992; Melanson, 1994). Meanwhile, in Europe, the European Economic Council (EEC) worked towards enforcing HACCP and, in 1991 and 1992, they published directives stipulating health conditions for the production and placing on the market of fishing products (Dos Santos *et al.*, 1994). In 1993, HACCP principles were formally included in EEC Directives, which were applicable to all industries including the fishing industry (Mortimore & Wallace, 1998). In 1994, the United States Food and Drug Administration (USFDA) proposed a seafood HACCP plan. This was followed-up in December 1995 by formal seafood regulations based on the principles of HACCP (USFDA, 1996). This served as a true test case for the rest of the United States food industry (Kushner, 1994).

In South Africa, HACCP became mandatory for seafood export to the European Union countries in December 1995 and to the USA in December 1997 (SABS, 1999). The implications of these regulations will, however, be discussed in more detail below. The history and development of HACCP and particularly its role in the international fishing arena shows that no fishing company can hide from HACCP implementation any longer.

## F. HACCP and the South African fishing industry

South Africa's fishing industry has been characterised by many political changes over the past few years. The major issues being the redistribution of quotas to promote equal opportunities and the changes that have been prompted by international HACCP requirements. Still, our living marine resources are in better shape and better managed than many others around the world (Mayekiso, 1998).

In the early 1990's, the South African fishing industry started to take note of HACCP regulations reported in Europe and the United States. The South African Bureau of Standards (SABS) and a few representatives of the larger fishing companies did their homework by visiting Canada, to ascertain how the HACCP system really works in their fishing industry on a national level. However, apart from this group, the industry was largely caught off guard when HACCP became mandatory for seafood export to the European Union countries in December 1995. This off course had tremendous financial implications and many companies could not comply in time and had to find new, often less lucrative markets for their products (Venneman, 1999). In December 1997, HACCP became mandatory for export of seafood to the United States (SABS, 1999), which narrowed the scope even more, for companies not having HACCP. Other countries such as Australia and the Far East started developing seafood HACCP plans, although so far nothing has been formalised in terms of regulations (Uys, 1998). At present, South African seafood processors cannot export their product to the developed world, without operating under HACCP controls (SABS, 1999).

Unlike with the rest of the food industry, the regulating body in the fishing industry, is the SABS. This body is responsible for the application of compulsory standard specifications for canned fish and meat products, smoked snoek, frozen fish and shell fish (Pretorius, 1998). In 1995, the EEC appointed the South African Bureau of Standards (SABS) as the competent authority to regulate HACCP in the South African fishing industry. In order to guide the industry in applying HACCP, a code of practice was specially developed by the SABS and published in 1998 (Truter, 1998).

The two largest sectors in South Africa's commercial fishing industry are the demersal and pelagic industries (Stuttaford 1999). The demersal industry generated an income of R 1104 M and the pelagic R 439 M in terms of wholesale processed value for 1997. This was 53 and 21%, respectively of the total wholesale processed value of seafood in South Africa. The demersal industry implies the fish species which are trawled (deepwater, midwater and inshore) or longlined and are processed and mostly sold fresh or frozen. Cape hake (*Merluccius capensis* and *Merluccius paradoxus*) is by far the largest constituent of this sector. Pelagic species are normally caught by purse seining and are canned or made into fishmeal, fish oil or bait. The main pelagic species is the South African pilchard (*Sardinops sagax*). The principal fish species caught during 1998 in South African waters are shown in Fig. 3. Hake is the single most caught fish species in South Africa (19.9%), followed by pilchard (17,1%), and anchovy (14,4%). Line caught fish (19.7%) and other demersal species (17,1%) are also significant, but it should be kept in mind that these are combinations of many fish species. Line caught fish consist of: snoek; tuna; yellowtail; mullet; squid etc., while other demersal species include: kingklip; monk; sole; horse mackerel etc. Hake has been top ranking and pilchard second since 1995. Before that (until 1964), hake was mostly second to anchovy with pilchard in third place. It should also be kept in mind that anchovy is processed as fishmeal and not normally intended for human consumption (Stuttaford, 1999). Apart from being economically the most important industries, hake and pilchard also rank high on the risk scale as shown in Table 1, pilchard being category one and hake category four.

The South African fishing industry has learnt over recent years that it is much more lucrative to export its seafood than it is to sell locally. Table 2 shows the income generated in South Africa from seafood exports during the period from 1994 to 1998. This is largely because of the weakening of the South African Rand against foreign currencies (Venneman, 1998). The main countries to which South Africa exports (in decreasing order) are: European Union; Japan; Australia; United States; DR Congo; Mozambique; Mauritius; Zimbabwe and Taiwan (Stuttaford, 1999). In 1996, seafood exports suddenly started increasing dramatically as is shown in Table 2.

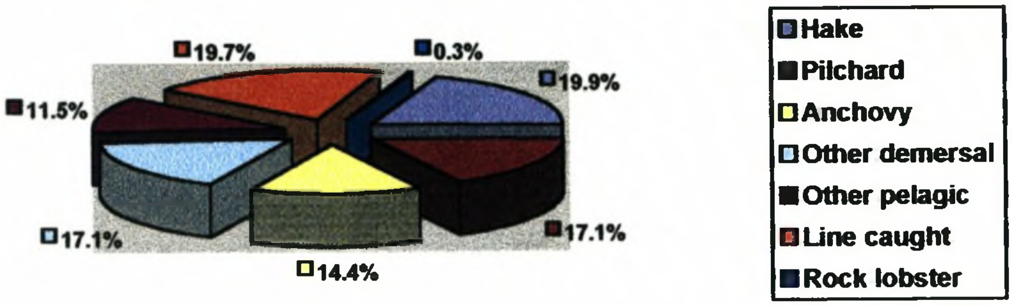


**Figure 3.** Percentage distribution of South African fish catches in 1998 (Stuttaford, 1999).

**Table 2.** South African seafood exports, 1994-1998 (Stuttaford; 1997; 1998; 1999).

| Year | Total (R) | % Growth |
|---|---|---|
| 1994 | 898 M | |
| 1995 | 867 M | -3.5 |
| 1996 | 873 M | 0.7 |
| 1997 | 1012 M | 13.7 |
| 1998 | 1353 M | 25.2 |

This coincided exactly with the time HACCP was introduced into the industry. This effectively sparked a new era for the fishing industry. The message was clear: for a company to survive, it had to export, and for it to export, it had to implement HACCP. In terms of economic growth in our country, it is, therefore, crucial that HACCP is implemented and functioning in the South African fishing industry. The two sectors with the most responsibility in this regard, are undoubtedly the hake and pilchard processing industries.

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# CHAPTER 3

# DEVELOPING A HACCP MODEL FOR A SOUTH AFRICAN PILCHARD CANNING OPERATION

## Abstract

A large portion of the total world fish catch is processed as canned fish. In South Africa the canned fish industry, and in particular, pilchard canning is economically very important. However, many potentially lethal hazards are associated with canned seafood. Very little scientific and technical guidance is available in this industry, to implement scientifically correct, practical HACCP systems. For this reason a HACCP model was designed at a canned fish case study company, which could be used, with slight modifications, by other pilchard canning companies who require HACCP guidance. The study was based on the seven principles recommended by the FAO & WHO (1997). The SABS methodology of (SABS, 1999) was followed to satisfy these principles.

## Introduction

Over 18% of the world seafood harvest is canned and thermally processed annually. This represents approximately 10 million tonnes of fish and 20 billion cans (Ababouch, 1992). In South Africa, the major locally produced canned seafood is pilchard (*Sardinops sagax*) and as discussed in Chapter 2 of this thesis, pilchard is after hake, the most economically important seafood species in this country. Canned pilchard constitutes approximately 15% of South Africa's total fish production (Stuttaford, 1998; Stuttaford, 1999). This results in approximately 70 000 tonnes of fish and 86 M cans (Campbell, 1998).

Canned seafood falls into the highest risk category when compared to other seafoods (Lee, 1977) and this is mainly due to the threat of *Clostridium botulinum*. In fact, the low acid canned seafood industry was amongst the very first industries to be regulated under Hazard Analysis Critical Control Point (HACCP) controls (Garrett *et al*, 1995). Although the risk is high, actual incidences of food poisoning in canned products are relatively low (Ahmed, 1992; Ababouch, 1992). This is mainly because canned products are normally well tested before selling on the marketplace. Because of its stability, canned seafood is available for testing over a longer period of time, whereas other seafoods have to be moved a lot quicker (Ahmed, 1992), but food safety incidences still do occur after the consumption of canned fish. Epidemiological data shows that these products have been involved mainly in outbreaks of botulism, histamine poisoning and Staphylococcal enterotoxin poisoning, which emphasises the need for HACCP controls (Ababouch,1992).

HACCP is designed as a preventative system. The idea is to control a problem as soon as possible in the production process, in order to minimise product losses and production and testing costs (Bauman, 1995). In the South African fish canning industry the approach has however, always been to focus on end-product testing rather than implementing preventative controls. Until the late 1990's, canning factories spent very little of their resources on preventative control. Yet, they got away with it because end-product control has always been done very well (Campbell, 1998). The South African Bureau of Standards (SABS) traditionally assumed the role of end-product controllers. On a routine basis, SABS inspectors grade end-products against compulsory national specifications and release or reject products accordingly (Stuttaford, 1999). This end-product testing still has a place in pilchard canneries, but should rather be seen as a verification activity. The focus should shift to prevention by using the HACCP approach.

The main objective of canning is to destroy spoilage and pathogenic organisms to protect the fish from future contamination. The basic production process involves catching of pilchards at sea, transporting the catch to the factory, cleaning, packing into three piece steel/tinplate cans, steam pre-cooking, hot filling with sauce, heat sterilisation, cooling and labelling. Presently there are seven pilchard canning factories in South Africa and the main activity is concentrated between Gansbaai and St. Helena Bay on the South Western Cape coast.

The aim of this study was to design a scientifically correct, yet practically implementable HACCP model for a pilchard canning operation, which is based on the Codex Alimentarius principles. The model was designed for a case study company, but could be used, with slight modifications, by other pilchard canning companies who require HACCP guidance.

## Scope of study

The case study company (CSC) produces canned fish, fish meal and fish body oil and utilises the services of separately owned purse-sein trawlers for fishing duties. The CSC is situated on the South-Western coast of South Africa and manufactures pilchards in tomato sauce and pilchard in chilli sauce. Products are marketed under the "Glenryck", "Lucky Star" or "Saldanha" labels to the general public.

The HACCP programme of the CSC was designed to be managed by a HACCP team, which consisted of a HACCP team leader (Production Manager), a HACCP administrator (Quality Controller) and two specialists (Factory Engineer and Cannery Manager).

## Product description

The product consists of headed and gutted pilchard (*Sardinops sagax*) cutlets which are packed into 73 x 111 mm (1M) or 52 x 89 mm (Jitney) steel/tinplate cans. Minimum nett weights are 425g (1M) and 155g (Jitney). Minimum drained weights are 318 g (1M) and 116 g (Jitney). The packing mediums are tomato sauce or chilli sauce. The target total soluble solid content of sauces expressed in ° Brix is 10.5 for tomato and 11.5 for chilli sauce. The average final product pH is 5.8 for tomato and chilli products (Uys,1998).

**Applying HACCP principles**

The seven HACCP principles of the FAO & WHO (1997) were followed in this study and the application of each principle is discussed (FAO & WHO, 1997).

***PRINCIPLE 1:*** *Conduct a hazard analysis. Prepare a flow diagram of the steps in the process. Identify and list the hazards and specify the control measures.*

A hazard analysis was conducted as described by (Leaper, 1992). Hazards were categorised as either microbial, chemical or physical and an additional category was added namely regulatory hazards. This was done in order to allow the HACCP programme to incorporate defect action points (DAP's). A DAP is defined as a point step or procedure where control can be applied to prevent non-compliance with mandatory, but non-safety requirements, that are regulated nationally or internationally (SABS, 1999). The South African fish canning industry is subjected to complying with the compulsory specification for canned fish (Anon, 1972). Certain issues arising from this specification are not food safety related, but should nevertheless be controlled. Therefore, the DAP term as recommended by (SABS, 1999), was used in this study in order to address these issues.

A preliminary list of hazards was drawn up under the categories: microbial; chemical; physical; and regulatory. Obvious, non-relevant hazards were then eliminated from the list. Subsequently, a flow diagram was prepared as is shown in Fig. 1, which described the logical flow of product. The next step was to work through each process step and to determine which of the above mentioned hazards were applicable at which step. The worksheets as recommended by SABS (SABS, 1999) were used as templates. The process of hazard analysis is shown in the first two columns of Table 1.

***PRINCIPLE 2:*** *Identify the Critical Control Points (CCPs) in the process.*

The CCP decision tree, as described in Chapter 2 of this thesis was used to determine whether points were CCPs. The same worksheets of the SABS, (SABS, 1999) were used to document decisions and are shown in Table 1. Columns 3 to 7 of Table 1 summarise decisions of how CCPs were selected. When it was proven that control at a point is not necessary, and that it would not be come a CCP, relevant references were given as proof.

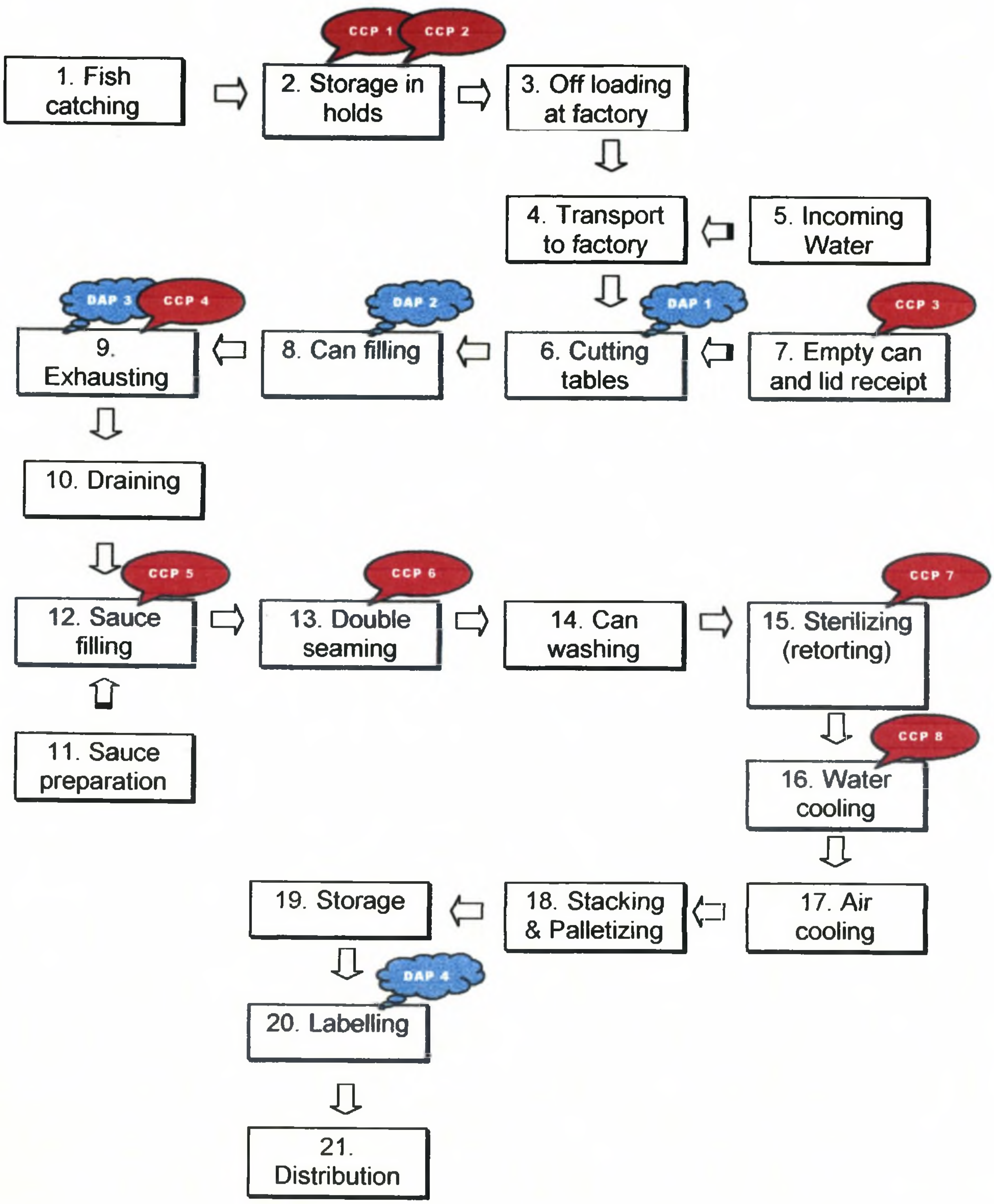


**Figure 1.** Process flow diagram: pilchards in tomato or chilli.

**Table 1.** Summary chart showing how CCPs were determined as per the SABS recommendations (SABS, 1999).

| STEP DESCRIPTION | HAZARD(S) (OR ESSENTIAL QUALITY DEFECTS) ASSOCIATED WITH STEP | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY ? | IS IT NECESSARY TO MODIFY PROCESS STEP OR PRODUCT ? | IS IT A CCP OR DAP ACCORDING TO CCP DECISION TREE ? | CCP/ DAP NR. |
|---|---|---|---|---|---|---|---|
| 1. Fish catching | **Microbial:**<br>• Presence of microbes | None | No | No, because microbial conditions only change after rigor mortis (Huss, 1994) | No | No | |
| 2. Storage in boat holds | **Microbial:**<br>• Insufficient cleaning of holds may lead to contamination of catch by histamine producing bacteria | Cleaning and sanitation procedures as described in the vessel master cleaning schedule (MCS) | Yes | Yes | No | CCP | CCP 1 |
| | • Incorrect storage on board may lead to growth of histamine producing bacteria | Time and temperature control, correct ice: fish ratio | Yes | Yes | No | CCP | CCP 2 |
| | **Chemical:**<br>• Contamination by on-board diesel or oil leaks | Adhering to the vessel maintenance schedule (VMS) as well as the vessel MCS | Yes | Yes | No | No | |
| 3. Off-loading into factory | **Microbial:**<br>• Microbial contamination or growth may occur | Time control of transit fish | Yes | No , exposure time at CSC is insufficient to pose a significant hazard (Lourens, 1998) | No | No | |
| | **Regulatory:**<br>• Fish may become damaged during off-loading | Correct pump design, adhering to the VMS | Yes | No, damaged fish will be sorted out at the cutting tables (step 6) | No | No | |

**Table 1.** (continued)

| STEP DESCRIPTION | HAZARD(S) (OR ESSENTIAL QUALITY DEFECTS) ASSOCIATED WITH STEP | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY ? | IS IT NECESSARY TO MODIFY PROCESS STEP OR PRODUCT ? | IS IT A CCP OR DAP ACCORDING TO CCP DECISION TREE ? | CCP/ DAP NR. |
|---|---|---|---|---|---|---|---|
| 4. Incoming sea water | **Microbial:**<br>• Contamination of fish with unclean water | Anti-microbial water treatment | No | No, not a food safety hazard, but it is a pre-requisite regulation for export to the European Union (Truter, 1998) , controlled sufficiently under the GMP programme (Strydom, 1999) | No | No | |
| 5. Transport into factory | **Microbial:**<br>• Contamination of fish by unclean surfaces | Adhering to factory MCS | Yes | No, the time is insufficient to cause significant growth (Lourens, 1998) | No | No | |
| | • Growth due to delays or bottlenecks during processing | Production planning | Yes | No, boats and volumes are too small to cause significant delays (Lourens, 1998) | No | No | |
| 6. Cutting tables | **Regulatory:**<br>• Incorrect sorting may lead to packing of incorrect species, parasite infected fish, broken fish, soft fish or fish containing excessive scales, green-feed, gut or tail pieces | Training of sorters, adhering to equipment maintenance schedule (EMS), post packing inspection and correction on conveyor belts | Yes | Yes | No | DAP | DAP 1 |
| 7. Empty can and lid receipt | **Microbial**:<br>•Can or lid defects by the manufacturer such as pinholes, cracks or poor seams rmay lead to eventual contamination | Supplier Quality Assurance (SQA) programme for incoming cans, stock rotation | Yes | Yes | No | CCP | CCP 3 |
| | **Chemical**:<br>•Contaminants such as Bisphenol-A may occur if laquer is defective | SQA programme for incoming cans | Yes | Yes | No | CCP | CCP 3 |

**Table 1.** (continued)

| STEP DESCRIPTION | HAZARD(S) (OR ESSENTIAL QUALITY DEFECTS) ASSOCIATED WITH STEP | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY ? | IS IT NECESSARY TO MODIFY PROCESS STEP OR PRODUCT ? | IS IT A CCP OR DAP ACCORDING TO CCP DECISION TREE ? | CCP/ DAP NR. |
|---|---|---|---|---|---|---|---|
| 8. Can filling | **Regulatory**:<br>• Under filling may lead to underweight end-product | Training of sorters, adhering to the EMS, post packing inspection and correction on conveyor belts | Yes | Yes | No | DAP | DAP 2 |
| | **Physical:**<br>• Poor can cleaning may lead to foreign objects in end-product | Adhering to proper can cleaning procedure and EMS | Yes | No, controlled sufficiently already under the Good Manufacturing Practices (GMP) programme (Strydom, 1999) | No | No | |
| 9. Exhaust box | **Microbial:**<br>• Incorrect exhausting may lead to too low initial temperatures which in turn may lead to underprocessing and low negative pressure (vacuum) | Belt speed (contact time), temperature control (sufficient steam supply) even heat distribution), adhering to the EMS | Yes | Yes | No | CCP | CCP 4 |
| | **Regulatory:**<br>• Incorrect exhausting may lead to excessive residual moisture, which may result in under-weight end-product or thin sauce | Belt speed, temperature control, adhering to the EMS | Yes | Yes | Yes | Yes | DAP 3 |
| 10. Draining | **Regulatory:**<br>• Incorrect draining may lead to excessive residual moisture, which may result in under-weight end-product or thin sauce | Drainer speed and adhering to the EMS and MCS | Yes | No, controlled sufficiently already under the GMP programme (Strydom, 1999) | No | No | |

**Table 1.** (continued)

| STEP DESCRIPTION | HAZARD(S) (OR ESSENTIAL QUALITY DEFECTS) ASSOCIATED WITH STEP | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY ? | IS IT NECESSARY TO MODIFY PROCESS STEP OR PRODUCT ? | IS IT A CCP OR DAP ACCORDING TO CCP DECISION TREE ? | CCP/ DAP NR. |
|---|---|---|---|---|---|---|---|
| 11. Sauce preparation | **Microbial:**<br>• Raw materials may contain heat resistant spores, or aflatoxins, which may not be affected by retorting | SQA programme for raw materials | Yes | No, pathogenic heat resistant spores will be destroyed during sterilising, the most resistant spores e.g *C. thermosacraliticum* are not pathogenic (Campbell, 1998) | No | No | |
| | **Chemical:**<br>• Raw materials may contain allergens, agricultural chemicals or toxic compounds | SQA programme for raw materials | No | No, a recent survey showed that these contaminants are not present at dangerous levels, in sauce ingredients (Uys & Gee, 1997)[a,b] | No | No | |
| | **Regulatory:**<br>• Incorrect sauce preparation or poor stock rotation may lead to thin sauce | SQA programme, adhering to sauce preparation procedures/ recipe, first-in-first-out stock rotation | Yes | No | No | No | |
| 12. Sauce filling | **Microbial:**<br>•Too low sauce temperature will lead to low initial temperatures/ poor vacuum | Correct temperature at filling | Yes | Yes | No | CCP | CCP 5 |
| | **Regulatory:**<br>• Under filling with sauce | Volume setting and adhering to EMS | Yes | No, controlled sufficiently already under the GMP programme (Strydom, 1999) | No | No | |
| 13. Double seaming | **Microbial:**<br>• Incorrect seaming may lead to eventual contamination of end-products | Adhering to double seaming procedures and EMS | Yes | Yes | No | CCP | CCP 6 |

**Table 1.** (continued)

| STEP DESCRIPTION | HAZARD(S) (OR ESSENTIAL QUALITY DEFECTS) ASSOCIATED WITH STEP | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY ? | IS IT NECESSARY TO MODIFY PROCESS STEP OR PRODUCT ? | IS IT A CCP OR DAP ACCORDING TO CCP DECISION TREE ? | CCP/ DAP NR. |
|---|---|---|---|---|---|---|---|
| 14. Can washing | **Microbial:**<br>• Too low washing temperatures may lead to cooling of cans and subsequent under processing | Temperature control at washer | Yes | No, controlled sufficiently already under the GMP programme (Strydom, 1999) | No | No | |
| | **Regulatory:**<br>• Incorrect washing may lead to soiled cans or labels not adhering to cans | Can washing procedures. Control of type and concentration of cleaning agent | Yes | No, controlled sufficiently already under the GMP programme (Strydom, 1999) | No | No | |
| 15. Sterilising / retorting | **Microbial:**<br>Under processing (insufficient exposure to processing times and temperatures) may occur which may lead to pathogen survival. Typical causes of under processing are: | | | | | | |
| | • Low incoming temperatures | Time control from steps 9 through 14 | Yes | Yes | No | CCP | CCP 7 |
| | • Insufficient venting time (time to displace air from the retort | Adhere to venting procedure | Yes | Yes | No | CCP | CCP 7 |
| | • Temperature drops such as power failures or insufficient steam supply | Adjust processing time according to procedure, adhere to EMS | Yes | Yes | No | CCP | CCP 7 |

**Table 1.** (continued)

| STEP DESCRIPTION | HAZARD(S) (OR ESSENTIAL QUALITY DEFECTS) ASSOCIATED WITH STEP | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY ? | IS IT NECESSARY TO MODIFY PROCESS STEP OR PRODUCT ? | IS IT A CCP OR DAP ACCORDING TO CCP DECISION TREE ? | CCP/ DAP NR. |
|---|---|---|---|---|---|---|---|
| 15. Sterilising / retorting (continued) | • Incorrect process control instrumentation | Adhere to calibration procedures | Yes | No, controlled sufficiently already under the GMP programme (Strydom, 1999) | No | No | |
| | • Uneven heat distribution in the retort due to design | Correct design and adhering to EMS | Yes | No, controlled sufficiently already under the GMP programme (Strydom, 1999) | No | No | |
| 16. Water cooling | **Microbial:**<br>• Contaminated water may enter cans through seams whilst under pressure | Adhere to cooling and chlorination procedures | Yes | Yes | No | CCP | CCP 8 |
| | • Too quick cooling may cause counter pressure which may damage can integrity | Adhere to cooling and chlorination procedures | Yes | Yes | No | CCP | CCP 8 |
| | • Over chlorination of water may cause rust, which in turn may affect can integrity | Adhere to cooling and chlorination procedures | Yes | Yes | No | CCP | CCP 8 |
| 17. Post retort cooling | **Microbial:**<br>• Staff may contaminate product by handling warm cans | Correct personal hygiene practices | Yes | No, controlled sufficiently already under the GMP programme (Strydom, 1999) | No | No | |

**Table 1.** (continued)

| STEP DESCRIPTION | HAZARD(S) (OR ESSENTIAL QUALITY DEFECTS) ASSOCIATED WITH STEP | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY ? | IS IT NECESSARY TO MODIFY PROCESS STEP OR PRODUCT ? | IS IT A CCP OR DAP ACCORDING TO CCP DECISION TREE ? | CCP/ DAP NR. |
|---|---|---|---|---|---|---|---|
| 18. Stacking and palletising | **Microbial:**<br>• Damaged to the can may affect its integrity | Adhering to stacking procedures | Yes | No, damaged cans are removed during labelling | No | No | |
| 19. Storage | **Microbial:**<br>• Damaged to the can may affect its integrity | Adhering to storage procedures | Yes | No, controlled sufficiently already under the GMP programme (Strydom, 1999) | No | No | |
| | • Incorrect storage conditions may lead to rust, which may affect can integrity | Adhering to storage procedures | Yes | No, controlled sufficiently already under the GMP programme (Strydom, 1999) | No | No | |
| 20. Labelling | **Regulatory:**<br>• Mislabelling of product | Adhering to labelling procedures | Yes | Yes | No | DAP | DAP 4 |
| 21. Distribution | **Regulatory:**<br>• Damage to the can may affect its integrity | Adhering to distribution procedures | Yes | No, consumers do not purchase damaged cans under normal circumstances, furthermore such cans get sorted out during retailing (Campbell, 1998) | No | No | |

During this process, the same methodology was used to select DAP's at points where safety would not be influenced, but the compulsory specification may be exceeded. As discussed in Chapter 2 of this thesis, an important aspect of HACCP is to only focus control on the critical issues. For this reason it was decided that from this point on, further attention is only given to CCPs and DAPs in terms of monitoring procedures, critical limits and corrective actions. A new form was designed and used to document these issues. The template as specified by the SABS (SABS, 1999) was used and is shown in Table 2.

***PRINCIPLE 3:*** *Establish Critical limits for every CCP*

Safe, yet achievable, critical limits were set for every CCP and DAP. Critical limits with appropriate references were referred to as "target levels and tolerances" in this study and are shown in column 6 of Table 2.

***PRINCIPLE 4:*** *Establish a monitoring system to ensure control of the CCP by scheduled testing or observations.*

Monitoring procedures were summarised under the headings: "monitoring and or test procedure"; "scope of check or sample size"; and "frequency required". This is shown in columns 3 through 5 of Table 2.

***PRINCIPLE 5:*** *Establish the corrective action to be taken when monitoring indicates that a particular CCP is out of control.*

Corrective action procedures are stipulated in column 7 in Table 2. The corrective action is linked to the critical limit. In other words, formal corrective action will be taken and documented if the specified critical limits are exceeded. In addition to the record noted in column 9, in each case a formal corrective action report will be completed by the relevant parties and authorised by the Production Manager, who will use these reports to manage trends. A blank example corrective action report is shown in Fig. 2.

***PRINCIPLE 6:*** *Establish documentation concerning all procedures and records appropriate to these principles and their application.*

It is important that a HACCP programme is well recorded and documented. The relevant records required on which CCP and DAP data will be recorded is shown in column 9 of Table 2. The personnel responsible for recording and also managing critical CCP and DAP data, are shown in column 8 of Table 2.

**Table 2.** Summary chart showing the procedures for the monitoring of CCPs or DAPs as per the SABS recommendations (SABS, 1999).

| NR. OF CCP OR DAP | DEFINITION OR DESCRIPTION OF CCP (DAP) | MONITORING AND/OR TEST PROCEDURE | SCOPE OF CHECK OR SAMPLE SIZE | FREQUENCY REQUIRED | TARGET LEVELS OR TOLERANCE(S) | CORRECTIVE ACTION REQUIRED | RESPONSIBLE PERSONS | REF.TO RECORD |
|---|---|---|---|---|---|---|---|---|
| CCP 1 | Storage in boat holds (cleanliness) | Visual hygiene inspection, includes checking for: microbial build-up; foul smells; loose fish; residual water; or diesel / oil | Thorough inspection of the floors walls & roofs of all four holds | 2 h after off loading & cleaning of vessel and 2 h before preparation for the next trip | No visible microbial build-up, foul smells, loose fish, dirty residual water , diesel or oils | Re-clean | Skipper to check, Shore Skipper to authorise | Daily vessel cleaning checklist |
| | | Contact plate counts (CPC) and histamine producing bacteria counts (HPB) | One contact plates and one HPB swab per surface (roof, floor, wall) per hold | Monthly | CPC < log 3.5 cfu/ 5cm², HPB < log 3 cfu/ 25cm² (refer to chapter 5 of this thesis) | Re-do monthly deep clean, redesign vessel to be more hygienic | Quality Controller (QC) to check, Shore Skipper to authorise | Monthly cleaning checklist, CPC and HPB report and boat cleaning schedule |
| CCP 2 | Storage in boat holds (temperature) | Temperature recording in holds | Continuous logging | Continuous | 10°C within 6 h afterwards < 8°C (USFDA, 1996) < 3°C within 6 h afterwards< 0°C within 16h (Truter, 2000) | Route to fishmeal plant | Skipper to check,Shore Skipper to authorise | Vessel temperature log |
| | | Off loading inspection | Internal probe temperature of fish as per sample schedule (Truter, 1998) | Upon off-loading and hourly thereafter | < 8°C (USFDA, 1996) | Route to fishmeal plant | QC to check, Shore Skipper to authorise | Off loading inspection form |

**Table 2.** (continued)

| NR. OF CCP OR DAP | DEFINITION OR DESCRIPTION OF CCP (DAP) | MONITORING AND/OR TEST PROCEDURE | SCOPE OF CHECK OR SAMPLE SIZE | FREQUENCY REQUIRED | TARGET LEVELS OR TOLERANCE(S) | CORRECTIVE ACTION REQUIRED | RESPONSIBLE PERSONS | REF.TO RECORD |
|---|---|---|---|---|---|---|---|---|
| DAP 1 | Cutting tables | Post cutting inspection on conveyor belts | 6 cans before entering exhaust box | Every 30 min | Correct species, no parasite infected fish, excessive scales, green feed, gut, broken fish, soft fish or tail pieces (Anon, 1972) | Physically remove can, replace incorrect fish, non compliances re-routed to fishmeal plant | QC to check, Canning Manager to authorise | Daily QC report |
| CCP 3 | Empty can and lid receipt | Visual can inspection, | Check for obvious damage at can feeder line | Continuous | No visual defects and no deviation from agreed can specifications (SABS, 1973) | Remove damaged cans | Can feeder QC to check, Canning Manager to authorise | Seam teardown report |
| | | Seam teardown test and side seam test | 6 cans per pallet | Every new delivery | No deviation from agreed can specifications (SABS, 1973) | Send back to supplier | QC to check, Canning Manager to authorise | Seam teardown report |
| | | Inspection of supplier process control data | Process control report per batch | To be done with every new delivery | No deviation from agreed can specifications (SABS, 1973) | Send back to supplier | QC to check, Canning Manager to authorise | Seam teardown report |
| | | Certificate of conformance from supplier | Inspect certificate | Annually or when can specs change | Certificate to show facets of empty cans are within legal limits (includes contaminants such as Bisphenol-A) | Send back to supplier | QC to check, Canning Manager to authorise | Certificate of conformance |

**Table 2.** (continued)

| NR. OF CCP OR DAP | DEFINITION OR DESCRIPTION OF CCP (DAP) | MONITORING AND/OR TEST PROCEDURE | SCOPE OF CHECK OR SAMPLE SIZE | FREQUENCY REQUIRED | TARGET LEVELS OR TOLERANCE(S) | CORRECTIVE ACTION REQUIRED | RESPONSIBLE PERSONS | REF.TO RECORD |
|---|---|---|---|---|---|---|---|---|
| DAP 2 | Can filling | On line visual can inspection and weighing | 6 cans before entering exhaust box | Every 30 min | Average weight: Jitney > 160g<br>1M > 476g (Strydom, 1999)<br><br>Visual: no cross filling (Anon, 1972) | Add extra cutlet to cans on-line<br><br>Repair cross filling on-line | QC to check, Canning Manager to authorise | Daily QC report |
| CCP 4 | Exhaust box | Probe temperature readings | Two cans, after exhaust box | Every 30 min | Temp > 71°C (SABS, 1973) | Adjust temperature and steam supply, adjust speed of belts, reject non-complying product | QC to check, Canning Manager to authorise | Daily QC report |
| DAP 3 | | Exhaust box reading, time | Check exhaust box thermometer | Every 20 min | Temp > 95°C, 30 min (Uys, 1998) | Adjust temperature and steam supply, adjust speed of belts, re-exhaust, reject non-complying product | QC to check, Canning Manager to authorise | Daily QC report |
| | | Drained weight check | Two cans, after exhaust box | Every 30 min | Average drained weight: Jitney > 116g<br>1M > 318g (Strydom, 1999) | Adjust temperature and steam supply, adjust speed of belts, drainer, reject non-complying product | QC to check, Canning Manager to authorise | Daily QC report |
| CCP 5 | Sauce filling | Filler temperature readings | Probe in filler | Every 30 min | Temp > 72°C | Rework, cook until temperature is achieved | QC to check, Canning Manager to authorise | Daily QC report |

**Table 2.** (continued)

| NR. OF CCP OR DAP | DEFINITION OR DESCRIPTION OF CCP (DAP) | MONITORING AND/OR TEST PROCEDURE | SCOPE OF CHECK OR SAMPLE SIZE | FREQUENCY REQUIRED | TARGET LEVELS OR TOLERANCE(S) | CORRECTIVE ACTION REQUIRED | RESPONSIBLE PERSONS | REF.TO RECORD |
|---|---|---|---|---|---|---|---|---|
| CCP 6 | Double seaming | Visual inspection | 20 cans per head | Every 30 min | No visual defects (SABS, 1973) | Stop seamer, quarantine product and destroy | Seam tester to check Seamer mechanic to authorise | Seam teardown report |
| | | Seam tear down | 2 cans per head | Every one h | No deviation from can specifications (SABS, 1973) | Stop seamer, quarantine product and destroy | Seam tester to check Seamer mechanic to authorise | Seam teardown report |
| | | | | | | In both instances notify SABS to conduct further tests | Production Manager to notify SABS | SABS records |
| | | | | | | Destroy or release as required | Production Manager to authorise | Seam teardown report |
| CCP 7 | Sterilising/ Retorting | Time between exhausting and retorting | Follow and time one can | Every 30 min | <1 h between exhausting and packing into retort (Hall, 2000) | Adjust process according to retort table (Hall, 2000) | Retort Operator to check Production Manager to calculate and authorise | Daily QC report |
| | | Venting time | Time temperature recording | Per retort batch | 6 min to reach 107°C (Hall, 2000) | Add an additional 2 min to reach 104°C, if temperature is still not reached vent for a further 2 min and start processing (Hall, 2000) | Retort Operator to check, production Manager to authorise | Daily QC report |

**Table 2.** (continued)

| NR. OF CCP OR DAP | DEFINITION OR DESCRIPTION OF CCP (DAP) | MONITORING AND/OR TEST PROCEDURE | SCOPE OF CHECK OR SAMPLE SIZE | FREQUENCY REQUIRED | TARGET LEVELS OR TOLERANCE(S) | CORRECTIVE ACTION REQUIRED | RESPONSIBLE PERSONS | REF.TO RECORD |
|---|---|---|---|---|---|---|---|---|
| CCP 7 (cont.) | Sterilising/ Retorting | Exposure to sterilisation time and temperature, calculation of Fo value | Continuous time-temperature recording by chart recorder Verify with mercury- in-glass thermometer | Per retort batch | Target level :1M : 90 min, 116°C, Fo value< 7, target level Jitney: 60 min, 116°C, Fo < 7 (Hall 2000) | Adjust process according to retorting table (Hall,2000)<br><br>Quarantine suspect cans, incubate 2 cartons per batch at 37°C for 14 days, destroy batch if any can shows swelling | Retort Operator c to check Production Manager to calculate and authorise<br><br>Production Manager to authorise | Daily retort form with attached chart<br><br>Daily retort form with attached chart |
| CCP 8 | Water Cooling | Monitoring of available chlorine and pH | 200 ml sample, 20 ml for chlorine, rest for pH | 30 min | 2 ppm ± 0.5 ppm available chlorine, pH = 6.8 - 7.4 (SABS, 1973) | Re- adjust chlorination process | QC to check, Production Manager to calculate and authorise | Daily QC report |

**Table 2.** (continued)

| NR. OF CCP OR DAP | DEFINITION OR DESCRIPTION OF CCP (DAP) | MONITORING AND/OR TEST PROCEDURE | SCOPE OF CHECK OR SAMPLE SIZE | FREQUENCY REQUIRED | TARGET LEVELS OR TOLERANCE(S) | CORRECTIVE ACTION REQUIRED | RESPONSIBLE PERSONS | REF.TO RECORD |
|---|---|---|---|---|---|---|---|---|
| CCP 8 (cont.) | Water Cooling | Cooling temperature | Reading of chart recorder and mercury-in-glass thermometer | Per retort batch | Cooling cycle only to start once temperature has reached 100°C (Hall, 2000) | Quarantine suspect cans, incubate 2 cartons per batch at 37°C for 14 days, destroy batch if any can shows swelling, sell as ration fish if rust is noted | Retort Operator to check Production Manager to calculate and authorise | Daily retort form with attached chart |
| | | | | | | Quarantine suspect cans, inspect seams for visual damage, incubate 2 cartons per batch at 37°C for 14 days, destroy batch if any can shows swelling or if excessive rust is noted | Retort Operator to check Production Manager to authorise | Daily retort form with attached chart |
| DAP 4 | Labelling | Visual inspection to ascertain that the code and label agrees and that only released cans are labelled | Inspect 4 cans per pallet, release form and labelling schedule | Before each new pallet | No mislabelled cans (Strydom, 1999) | Reject | Labelling manager to check, Production manager to authorise | Labelling report |
| | | Visual inspection to ascertain that no damaged or rusted cans are labelled | Continuous on-line | Continuous | No damaged or rusted cans (Strydom, 1999) | Reject | Labelling operator to check, Labelling manager to authorise | Labelling report |

In order to ensure that all forms are collected and completed correctly, a records checklist was designed to facilitate this task. This record is used by the Quality Controller at the end of a shift and is eventually attached to the front of the daily record file, and filed as a record for a period of two years. A blank example for such a form is shown in Fig. 3. A similar record is used for monthly activities such as CPC and HPB reports, monthly cleaning and maintenance schedules and water reports.

***PRINCIPLE 7:*** *Establish verification procedures, which include appropriate supplementary tests, together with a review, which confirms that HACCP is working effectively.*

The term verification and its importance is described in detail in Chapter 6 of this thesis. The verification activities required in this HACCP study are summarised below in terms of validation, targeted sampling and testing, CCP verification, system verification and market feedback.

The HACCP system was validated scientifically by third party experts, and technically by non-HACCP team members of the CSC. This took place before implementation. Attention was given to correctness of especially CCPs, target levels and tolerances as well as monitoring activities.

Targeted sampling and testing has traditionally always been very prominent in the South African fish canning industry. Although it was always seen as the backbone of quality assurance, it is now seen as a verification activity to ensure that the HACCP system is working. The main targeted sampling and testing activity is end product inspection by the SABS. This involves inspecting a representative number of samples of each batch against the compulsory standard specifications detailed in Anon (1972). A further important sampling and testing activity, which is facilitated by SABS inspectors, is the incubation of reference samples at accelerated conditions of 37°C, a temperature where microbial and chemical activity is optimum. These reference samples are then monitored for blowing. Pending the outcome of their tests, the SABS inspectors will release the product for sale, grade the product in an appropriate quality category and issue a certificate.

CCP verification activities include temperature logging on pilchard vessels, and throughout the factory similar to the study in Chapter 6, as well as heat distribution studies in steamboxes and in retorts.

System verification takes place in the form of an internal first party audit. This is conducted three monthly by the HACCP team. All findings are recorded and to ensure that follow-up of audit findings are taken seriously, the report is circulated to top management. Furthermore, system verification also takes place in the form of a formal annual third party audit. Similarly, this report is circulated to the top management, to ensure their commitment.

The system is lastly verified by means of market feedback. All customer complaints are recorded and analysed. A monthly summary is generated and is used

| CORRECTIVE ACTION REPORT | | | |
|---|---|---|---|
| PRODUCTION CODE: | | DAP/CCP NO: | |
| PROBLEM DESCRIPTION: | | | |
| DATE: | TIME: | RECORDED BY:: | RESPONSIBLE:: |
| CORRECTIVE ACTION TAKEN: | | | |
| DATE: | TIME: | RECORDED BY:: | RESPONSIBLE: |
| PROBLEM CLOSED OUT: | | | |
| DATE: | TIME: | PRODUCTION MANAGER:: | |

**Figure 2.** Corrective action report, as used in the HACCP programme.

| DAILY RECORDS CHECKLIST | | |
|---|---|---|
| DATE: | RECORDED BY: | |
| Check boxes with ✓if form is received and signed off. Otherwise mark with x and complete the comments column. | | |
| **Record** | **✓or x** | **Comments:** |
| Daily vessel cleaning checklist | | |
| Vessel temperature log | | |
| Off loading inspection form | | |
| Seam teardown report :empty cans | | |
| Seam teardown report :processed cans | | |
| Daily QC report | | |
| Daily retort form for each | | |
| Retort charts | | |
| Labelling report | | |
| AUTHORISED BY: | | |

**Figure 3.** Daily records checklist, as used in the HACCP programme.

as a management tool to measure the overall efficacy of the HACCP plan. Review activities are crucial in ensuring that the HACCP system does not loose momentum, remains functional, and is constantly improving. HACCP review takes place in the form of HACCP team meetings. During such meeting, HACCP implementation tasks and responsibilities are listed and allocated to team members. At each new HACCP review meeting, completed items are removed from the old list, incomplete items are retained and new items are added if required. A short executive summary of the overall progress is compiled by the HACCP team leader and circulated to top management, to ensure their commitment. The form in Fig. 4 is used to minute review meetings.

Review is scheduled to take place on a monthly basis during the HACCP implementation stage and three monthly whilst the programme is functioning. Typical items on the list during implementation phases are: HACCP documentation compiling; modification of buildings; upgrading of pre-requisite programmes such as GMP and SQA, etc. After implementation, typical issues for review are: change in consumer use; change in equipment; formula changes; streamlining of recording forms etc.

## Discussion and conclusions

It must be stressed that this model only represents a small part of the total HACCP programme at the CSC. It only summarises the thinking process behind interpreting the seven Codex Alimentarius HACCP principles. At the time, it was proved to be as a good starting point, from which, the 12 HACCP implementation steps were followed, HACCP procedures were written, recording forms and checklists were designed, and a HACCP manual was compiled.

It is also important to realise that this model relies on the fact that the pre-requisite programmes, GMP and SQA are fully functional, because in many instances these systems were listed as control measures.

This model was specifically designed for the CSC and may be totally different for other canning companies. A similar canning company might arrive at more, less or different CCPs, depending on their specific conditions. The point of vessel cleaning for instance, will probably not be a CCP for most canning companies, because cleaning activities are theoretically part of the GMP programme, which is not addressed by HACCP. A company should, therefore, assess its own risk and customise HACCP to meet their specific needs. Nevertheless, this model should, on the whole, be useful to be used as a guideline for other South African fish canning factories, who wish to implement HACCP.

HACCP REVIEW MEETING MINUTES

| | |
|---|---|
| Date: previous meeting | |
| Date this meeting: | |

| Present: | Apologies: |
|---|---|
| | |

| Executive summary: |
|---|
| |
| Signed, top management: |

| HACCP review Activities | | | |
|---|---|---|---|
| No. | Item | Responsible | Target Date |
| | | | |

**Figure 4.** HACCP review meeting minutes.

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# CHAPTER 4

# DEVELOPING A HACCP MODEL FOR A FRESH CAPE HAKE PROCESSING OPERATION

**Abstract**

Cape hake is commercially the most important fish species in South Africa, and is mostly sold whole and fresh to the international market. This product is seen as relatively low risk in terms of food safety, but should still be controlled by means of the HACCP system. Very little scientific and technological guidance is available to this industry, to implement scientifically correct, practical HACCP systems. For this reason a HACCP model was designed for a case study company, which could be used by other fish processors for guidance. The study was based on the seven principles recommended by the FAO & WHO (1997). The SABS methodology (SABS,1999) was followed to satisfy these principles.

**Introduction**

As discussed in Chapter 2 of this thesis, Cape hake is the most caught and economically, the most important fish species in South Africa. Cape hake is a white fleshed and low fat fish, which represents both *Merluccius capensis* and *Merluccius paradoxus* species (Stuttaford, 1999). Both are highly perishable due to their soft texture, neutral pH (6.6 – 7.0) and high water activity (0.995) (Venneman, 1996).

Although hake is, as in the case with other whitefish, highly perishable, its risk in terms of food safety is very low. Consequently very few people normally become ill after consuming such products (Huss, 1994). According to the table specified by Garrett *et al.* (1995), in Chapter 2 of this thesis, hake would fall into category 4 of 5, the second lowest risk category. The low risk can be attributed to the fact that under normal circumstances, spoilage bacteria grow on fresh white fish before pathogens do. The fish has to be in an advanced state of spoilage before dangerous levels of pathogens become present. This advanced state of spoilage is also associated with offensive and putrid odours, which means that consumers would most likely not ingest the fish in the first place (Huss, 1994).

Nevertheless, white fish is still exposed to many potential hazards, which, although it may not harm a person severely, still technically are food safety hazards. Examples being contamination from pathogens via water, food workers, dirty equipment and the presence of parasites (Institute of Medicine, 1991). It is essential that the processing of hake should be managed by means of a formal quality management programme such as HACCP (Venneman, 1996).

The aim of this study was to design a scientifically correct, yet practically implementable HACCP model for a fresh Cape hake processing operation based on Codex Alimentarius principles. A further aim of the study was to show the difference in HACCP approaches between Chapters 3 and 4 of this thesis, in other words, the difference in HACCP approaches between a highly thermally processed product and an unprocessed fresh product.

## Scope of study

The case study company (CSC) trawls and processes wholesale fish and operates from the Cape Town harbour. The target market is mainly Spain as well as other European Union countries. The product selected for the study was head-on gutted Cape Hake, which is sold wholesale and packed in insulated polystyrene boxes together with an ice bottle as chilling medium.

The HACCP programme of the CSC is designed to be run by a HACCP team, which consists of a HACCP team leader (Production Manager), a facilitator (Assistant Production Manager), an administrator (Quality Controller) and relevant specialists.

## Product description

The product selected for the study was head-on gutted Cape hake (*Merluccius capensis* and *Merluccius paradoxus*), which is sold wholesale and packed in insulated polystyrene boxes with a 600 ml ice in plastic pack as chilling medium. The target nett weight of the final product is 20 kg, but depends on the hake size packed. Hake sizes may vary from 180 to 600 mm in length.

## Applying HACCP principles

The seven HACCP principles of FAO & WHO (1997) were followed in this study and the application of each principle is discussed (FAO & WHO, 1997):

***PRINCIPLE 1:*** *Conduct a hazard analysis. Prepare a flow diagram of the steps in the process. Identify and list the hazards and specify the control measures.*

A hazard analysis was conducted as described by (Leaper, 1992). Hazards were categorised as either microbial, chemical or physical and an additional category was added namely regulatory hazards. This was done in order to allow the HACCP programme to incorporate defect action points (DAPs). A DAP is defined as a point step or procedure where control can be applied to prevent non-compliance with mandatory, but non-safety requirements, that are regulated nationally or internationally (SABS, 1999). For this study the term DAP was used to address aspects which are not food safety related, but are required in terms of SABS 570 Man 005 (Truter, 1998).

A preliminary list of hazards was drawn up under the categories: microbial; chemical; physical; and regulatory. Obvious non-relevant hazards were then eliminated from the list. Subsequently, a flow diagram was prepared as is shown in Fig.1, which describes the logical flow of product. The next step was to work through each process

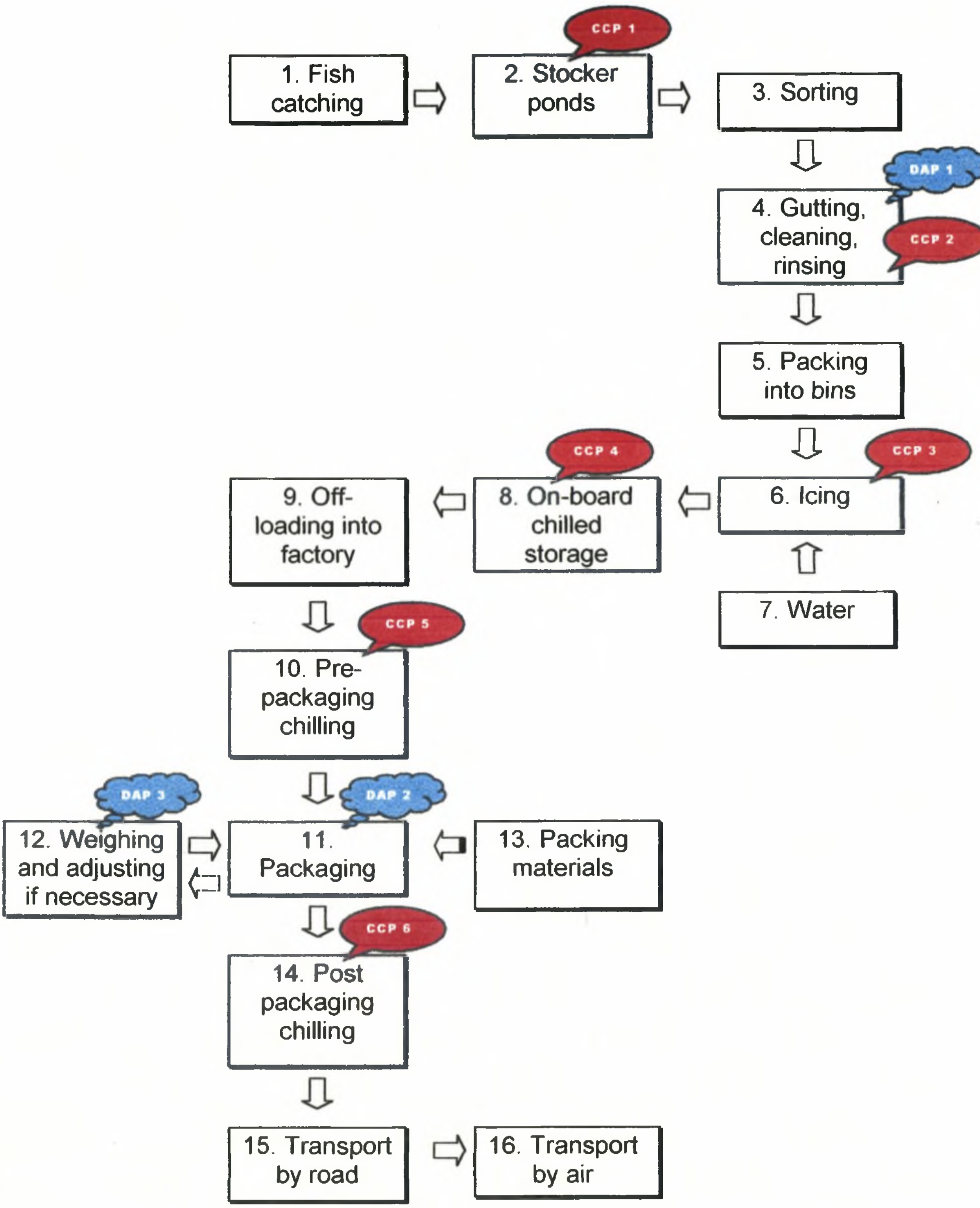


Figure 1. Process flow diagram for fresh whole Cape hake.

step and to determine which of the above mentioned hazards are applicable at which step. The worksheets of (SABS, 1999), were used as templates. The process of hazard analysis is shown in the first two columns of Table 1.

***PRINCIPLE 2:*** *Identify the Critical Control Points (CCPs) in the process.*

The CCP decision tree as described in chapter 2 of this thesis was used to determine whether points were CCPs. The same worksheets of the SABS, (SABS, 1999) were used to document decisions and are shown in Table 1. Columns 3 to 7 of Table 1 summarise decisions of how CCPs were chosen. When it was proven that control at a point is not necessary, and that it would not become a CCP, relevant references were given as proof.

During this process, the same methodology was used to select DAPs at points where safety would not be influenced, but the compulsory specification may not be complied with.

***PRINCIPLE 3:*** *Establish critical limits for every CCP*

Safe, yet achievable, critical limits were set for every CCP and DAP. Critical limits with appropriate references were referred to as "target levels and tolerances" in this study and are shown in column 6 of Table 2.

***PRINCIPLE 4:*** *Establish a monitoring system to ensure control of the CCP by scheduled testing or observations.*

Monitoring procedures were summarised under the headings: "monitoring and or test procedure"; "scope of check or sample size"; and "frequency required". These are shown in columns 3 through 5 of Table 2.

***PRINCIPLE 5:*** *Establish the corrective action to be taken when monitoring indicates that a particular CCP is out of control*

Corrective action procedures are stipulated in column 7 in Table 2. The corrective action is linked to the critical limit. In other words, formal corrective action will be taken and documented if the specified critical limits are exceeded. In addition to the record noted in column 9, in each case a formal corrective action report will be completed by the relevant parties and authorised by the Production Manager, who will use these reports to manage trends. A blank example corrective action report is shown in Fig. 2, in Chapter 3 of this thesis.

**Table 1.** Summary chart showing how CCPs were determined as per SABS recommendations (SABS, 1999).

| STEP DESCRIPTION | HAZARDS (OR ESSENTIAL QUALITY DEFECTS) | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY? | IS IT NECESSARY TO MODIFY PROCESS, STEP OR PRODUCT? | IS IT A CCP OR DAP ACCORDING TO THE CCP DECISION TREE | CCP/DAP NO. |
|---|---|---|---|---|---|---|---|
| 1. Fish catching | **Microbial:**<br>• Presence of microbes | None | No | No, because microbial conditions only changes after rigor mortis (Huss,1994) | No | No | |
| 2. Stocker pond | **Microbial:**<br>• Growth of microbes | Limit the amount of fish in a drag<br>Time, temperature control | Yes | Yes | No | CCP | CCP 1 |
| 3. Sorting | **Regulatory:**<br>• Incorrect size or incorrect species sorting | Sorting procedures | Yes | No, during a further step (packaging), this hazard can be eliminated | No | No | |
| 4. Gutting, cleaning and rinsing | **Microbial:**<br>• Cross contamination of flesh by gut content | Adhering to gut removal Procedure<br>Adequate rinsing with fresh seawater<br>Adhering to master cleaning schedule (MCS) | Yes | Yes | No | CCP | CCP2 |
| | Parasites may not have been removed | Parasite sorting procedure | Yes | Yes | No | DAP | DAP 1 |

**Table 1.** (continued)

| STEP DESCRIPTION | HAZARDS (OR ESSENTIAL QUALITY DEFECTS) | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY? | IS IT NECESSARY TO MODIFY PROCESS, STEP OR PRODUCT? | IS IT A CCP OR DAP ACCORDING TO THE CCP DECISION TREE | CCP/DAP NO. |
|---|---|---|---|---|---|---|---|
| 5. Packing into bins | **Microbial:**<br>• Cross contamination via dirty bins or handling | Bin cleaning procedure<br>Personnel hygiene procedure. | Yes | No, addressed in the GMP programme under cleaning and sanitation and personnel hygiene procedures (Cooper, 1999) | No | No | |
| 6. Icing | **Microbial:**<br>• Growth due to insufficient ice ratio | All fish to be covered properly with ice in order to reach temperature | Yes | Yes | No | CCP | CCP 3 |
| 7. Water | **Microbial:**<br>• Cross contamination from water to fish in the ice making process | Ice making procedures.<br>Adhering to the MCS | Yes | No, addressed in the GMP programme, under water control procedures and cleaning and sanitation procedures (Cooper, 1999) | No | No | |

**Table 1.** (continued)

| STEP DESCRIPTION | HAZARDS (OR ESSENTIAL QUALITY DEFECTS) | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY? | IS IT NECESSARY TO MODIFY PROCESS, STEP OR PRODUCT? | IS IT A CCP OR DAP ACCORDING TO THE CCP DECISION TREE | CCP/DAP NO. |
|---|---|---|---|---|---|---|---|
| 8. On board storage | **Microbial:** • Growth due to poor temperature control | Time, temperature control | Yes | Yes | No | CCP | CCP 4 |
| 9. Off-loading into factory | **Microbial:** • Growth due to bins being removed too slowly or by bottlenecks | Off-loading procedure, time control | Yes | No, controlled in the GMP programme under production scheduling | No | No | |
| 10. Pre packaging chilling | **Microbial:** • Growth due to poor temperature control | Time temperature control | Yes | Yes | No | CCP | CCP 5 |
| 11. Packaging | **Microbial:** • Cross contamination by surfaces or handling | Personnel hygiene procedure. Adhering to the MCS | Yes | No, addressed in the GMP programme under cleaning and sanitation and personnel hygiene procedures (Cooper, 1999) | No | No | |

**Table 1.** (continued)

| STEP DESCRIPTION | HAZARDS (OR ESSENTIAL QUALITY DEFECTS) | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY? | IS IT NECESSARY TO MODIFY PROCESS, STEP OR PRODUCT? | IS IT A CCP OR DAP ACCORDING TO THE CCP DECISION TREE | CCP/DAP NO. |
|---|---|---|---|---|---|---|---|
| 11. Packaging (cont.) | **Regulatory**:<br>• Incorrect size or incorrect specie packing | Packing procedures | Yes | Yes | No | No | DAP 2 |
| 12. Weighing | **Regulatory:**<br>• Incorrect weight | Calibration procedures<br>Verification procedure | Yes | Yes | No | No | DAP 3 |
| 13. Packing materials | **Chemical:**<br>•Packing materials might contain substances which may react with fish flesh to form unsafe substances (e.g. Bisphenol-A) | Supplier Quality Assurance (SQA) programme | Yes | No, controlled sufficiently under the SQA programme (Cooper, 1999) | No | No | |

**Table 1.** (continued)

| STEP DESCRIPTION | HAZARDS (OR ESSENTIAL QUALITY DEFECTS) | PREVENTATIVE CONTROL MEASURES | CONTROL MEASURES IN PLACE? | CONTROL NECESSARY? | IS IT NECESSARY TO MODIFY PROCESS, STEP OR PRODUCT? | IS IT A CCP OR DAP ACCORDING TO THE CCP DECISION TREE | CCP/DAP NO. |
|---|---|---|---|---|---|---|---|
| 14. Post packaging chilling | **Microbial:**<br>• Growth due to poor temperature control | Time, temperature control | Yes | Yes | No | CCP | CCP 6 |
| 15. Transport by road | **Microbial:**<br>• Growth | Control by transport company | No, responsibility of transporting company | Yes | No | No | |
| 16. Transport by air | **Microbial:**<br>• Growth | Control by transport company | No, responsibility of airline company | Yes | No | No | |

**Table 2.** Summary chart showing the procedures for the monitoring of CCPs and DAPs as per the SABS recommendations (SABS, 1999).

| NO. OF CCP OR DAP | DEFINITION OR DESCRIPTION | MONITORING OR TEST PROCEDURE | SCOPE OF CHECK OR SAMPLE SIZE | FREQUENCY REQUIRED | TARGET LEVELS OR TOLERANCES | CORRECTIVE ACTION REQUIRED IN RESPECT OF NON-CONFORMING PRODUCT | RESPONSIBLE PERSONS | REFERENCE TO RECORD TO BE COMPLETED |
|---|---|---|---|---|---|---|---|---|
| CCP 1 | Stocker ponds | Monitor drag time and tonnage per drag | Time, calculate tonnage | Every drag | As per dragging specifications for each net (Cooper, 1999) | Extra inspection points at sorting Remove damaged fish. Quarantine batch, do further microbial tests when on land | Skipper | Skippers fishing log |
| DAP 1 | Gutting, cleaning, rinsing | Visually inspect for parasites during gutting and cleaning | Every fish | Continuous | No parasites present | Discard infected fish according to dumping procedure | Processing staff, overall responsibility lies with the Foreman | Daily processing record |
| CCP 2 | Gutting, cleaning, rinsing | Inspect whether properly cleaned | Visually inspect all fish | Continuous | All gut removed and rinsed properly and no parasites present | Re-gut, clean and rinse | Gutter to inspect, Foreman to supervise | Daily processing record |
| CCP 3 | Icing | Inspect whether fish is properly iced | Visually inspect bins | Every 30 min | Pre determined fish to ice ratio Fish totally covered in ice | Re-ice | Foreman | Daily processing record |

**Table 2.** (continued)

| NO. OF CCP OR DAP | DEFINITION OR DESCRIPTION | MONITORING OR TEST PROCEDURE | SCOPE OF CHECK OR SAMPLE SIZE | FREQUENCY REQUIRED | TARGET LEVELS OR TOLERANCES | CORRECTIVE ACTION REQUIRED IN RESPECT OF NON-CONFORMING PRODUCT | RESPONSIBLE PERSONS | REFERENCE TO RECORD TO BE COMPLETED |
|---|---|---|---|---|---|---|---|---|
| CCP 4 | On-board chilled storage | Probe temperature reading | One fish centre of bin | 30 min | 3°C within 6 hours after catching (Chapter 6) | Discard fish according to dumping procedure | Foreman | Daily processing record |
| | | Temperature logging in chill room | Air temp in chiller | Continuous | < 5°C (Cooper, 1999) | Re-ice fish | Foreman | Logger print out |
| CCP 5 | Pre-packaging chilling | Probe temperature reading before chilling | One fish centre of bin | 30 min | < 3°C (Cooper, 1999) | Quarantine, sell to different market | QualityController (QC) | Daily factory QC record |
| | | Temperature logging in chill room | Air temp in chiller | Continuous | < 3°C (Cooper, 1999) | Place in a different chiller | QC | Logger print out |
| DAP 2 | Packaging | Checks during packing Controlling of labels | Visually inspect | Continuous Report every 30 min. | No mispacking or mislabelling | Rework | Packing foreman: continuous QC: 30 min | Daily processing record |

**Table 2.** (continued)

| NO. OF CCP ORDAP | DEFINITION OR DESCRIPTION | MONITORING OR TEST PROCEDURE | SCOPE OF CHECK OR SAMPLE SIZE | FREQUENCY REQUIRED | TARGET LEVELS OR TOLERANCES | CORRECTIVE ACTION REQUIRED IN RESPECT OF NON-CONFORMING PRODUCT | RESPONSIBLE PERSONS | REFERENCE TO RECORD TO BE COMPLETED |
|---|---|---|---|---|---|---|---|---|
| DAP 3 | Weighing and adjusting | Spot checks by QC | One bin | Hourly | 10 g difference max. (Cooper,1999) | Re-pack until weight is achieved | QC | Daily factory QC record |
| CCP 7 | Pre-packaging chilling | Probe temperature reading before chilling | One fish centre of bin | 30 min | < 3°C (Cooper,1999) | Quarantine, sell to different market | QC | Daily factory QC record |
| | | Temperature logging inside chill room | Air temp inside chiller | Continuous | < 3°C (Cooper,1999) | Place in a different chiller | QC | Logger print out |

***PRINCIPLE 6:*** *Establish documentation concerning all procedures and records appropriate to these principles and their application.*

It is important that a HACCP programme is well recorded and documented. The relevant records required on which CCP and DAP data will be recorded, is shown in column 9 of Table 2. The personnel responsible for recording and also managing critical CCP and DAP data, are shown in column 8 of Table 2. In order to ensure that all forms are collected and completed correctly, a records checklist was designed to facilitate this task.

This record is used by the Quality Controller at the end of a shift and is eventually attached to the front of the daily record file, and filed as a record for a period of two years. A blank example for such a form is shown in Fig. 2 of Chapter 3 of this thesis.

***PRINCIPLE 7:*** *Establish verification procedures, which include appropriate supplementary tests, together with a review, which confirms that HACCP is working effectively.*

After the system had been implemented, it was validated by means of an external third party HACCP audit by the SABS and repeated annually thereafter. Internal audits were conducted six monthly by the HACCP team. Findings of both external and internal audits were recorded and circulated to top management, to ensure that follow-up of audit findings were taken seriously.

Since most of the CCP's were linked to time and temperature control, the main verification activity for this study was to conduct time temperature logging studies of the process. This activity is described in detail in Chapter 6 of this thesis.

Targeted sampling and testing was seen as a verification activity to ensure that the HACCP system is working. This took place in the form of end-product inspection by SABS. This involves inspecting a representative number of end-products per batch, at the airport before departure. SABS inspectors inspect the fish according to European Union export requirements. A certificate is issued if the sample complies and the batch is rejected for export if the sample does not comply.

The system was lastly verified by means of market feedback. All customer complaints were recorded and analysed. A monthly summary was generated and used as a management tool to measure the overall efficacy of the HACCP plan.

Review activities are crucial in ensuring that the HACCP system does not loose momentum, remains functional, and is constantly improving. In this case HACCP reviews took place in the form of HACCP team meetings. During such meetings, HACCP implementation tasks and responsibilities were listed and allocated to team members. At each new HACCP review meeting, completed items were removed from the old list, incomplete items were retained and new items were added if required.

A short executive summary of the overall progress was compiled by the HACCP team leader and circulated to top management, to ensure their commitment. The form as illustrated in Fig. 3 of Chapter 3 of this thesis was used for this purpose.

## Discussion and conclusions

It should be stressed that this model only represents a small part of the total HACCP programme at the CSC. It only summarises the thinking process behind interpreting the seven Codex Alimentarius HACCP principles.

It is also important to realise that this model relies on the fact that the pre-requisite programmes Good Manufacturing Practices (GMP) and Supplier Quality Assurance (SQA) are fully functional, because in many instances these systems were listed as control measures.

When compared, this HACCP model differs significantly from the canned fish model as described in Chapter 3 of this thesis. There are a lot less CCPs and DAPs in this study due to the fact that the process is much less complicated. The CCPs in this study were mostly related to cold storage while the CCPs in the canned fish model (Chapter 3) were much more diverse, ranging from cold storage, to thermal processing, seaming and cooling. In terms of spoilage, fresh fish is much more unstable than canned fish, and one would have expected more CCPs. However, it has been shown that canned fish is potentially much more unsafe than fresh fish because hazards are not as easily detectible by the consumer. In fresh fish it is very easy to detect when a fish is spoilt long before it is unsafe. Canned fish, on the other hand, is exposed to thermal and anaerobic conditions, which alter the microbial characteristics and food safety risk. It seems that the hazards are "hidden" from the consumer in the closed can. It, therefore, makes sense that a canned fish HACCP study is more complex, with more CCP's and requires more effort to manage, than a fresh fish HACCP study.

This model should, on the whole, be useful to be used as a guideline to other South African fresh fish processing factories, who wish to implement HACCP.

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# CHAPTER 5

# VALIDATING AND CONTROLLING A CRITICAL CONTROL POINT IN A SOUTH AFRICAN PILCHARD CANNING OPERATION

## Abstract

Histamine poisoning is a potential food safety hazard in canned pilchards. The histamine is formed during post mortem bacterial decarboxylation of the amino acid histidine and or by autolysis. During the implementation of the HACCP system at a South African pilchard canning company, the question was raised whether this hazard is applicable. A study was conducted to validate whether this point was in fact a CCP, and if so, what the control measures and target levels would be.

It was found that the potential for histamine poisoning existed, due to the fact that boat holds were not cleaned adequately. Histamine producing bacteria could grow on dirty surfaces and contaminate the catch with histamine, which could not be destroyed by subsequent canning process steps. Swabs were collected from boat hold surfaces. Viable contact plate counts and histamine producing bacteria counts were performed. Results showed high counts in both instances, which validates that the point of hold cleaning is a CCP.

Control measures were implemented in the form of a master cleaning schedule. Viable contact plate counts and histamine producing bacteria counts were repeated after the master cleaning schedule had been implemented. Counts decreased significantly in both instances, which validates the efficacy of the control measures.

Ecologically justified, achievable target levels were calculated for viable contact plate counts and histamine producing bacteria counts, which in future could be used in the HACCP plan of the case study company.


## Introduction

The challenge for fishing companies is to implement HACCP systems, which are both scientifically correct and practically actionable on the factory floor. In Chapter 3 of this thesis, a model for such a system was presented which could meet these criteria. From this model it transpired that the selection of critical control points (CCP's) 2 through 8 were easily qualified, and that quantifiable, well defined, manageable critical limits existed. Even non-technical factory personnel did not struggle to understand why these points were critical, because care had always been taken at these points in the past, albeit mostly informally. CCP no. 1, namely cleaning of the boat holds, had however, never been verified as critical and no measurable limits existed prior to the HACCP study.

The company, at which the case study was conducted, hereinafter referred to as the Case Study Company (CSC), catches their pilchards with trawlers by means of purse-seining. This involves locating schools of fish with sonar and encircling the school with a net. The net is then closed in the same way as a purse, trapping the fish inside (Jensen & Hansen, 1983). Depending on the size of the boat and sea conditions, catches can vary from 0 to 80 tonnes (Lourens, 1998). The trapped fish are then pumped into holds where they are chilled either by direct ice contact, chilled sea water, or refrigerated sea water. Purse -seiners have four available holds. A typical purse-seiner in action is shown in Fig. 1. The top and inside views of the fish holds of a purse-seiner used by the CSC are shown in Fig. 2.

Temperatures inside the holds vary substantially during transport to the cannery and depends on a number of factors including: length of trip; sea temperature; air temperature; and size of catch. The length of such a trip may vary from 2 to 36 h (Lourens, 1998). A typical temperature profile of one of the CSC wooden purse-seiners during operation, has shown that temperature can reach as high as 14.5°C in the holds, and that there may be up to a 14°C fluctuation at any given time in different parts of the holds (Uys *et al.*, 1998). Upon arrival at the cannery, fish is pumped from the holds into the factory for processing. After offloading, the vessel and in particular the holds are cleaned for the next trip (Lourens, 1998).

During the HACCP study at the CSC, it was found that the step of cleaning the holds was controlled very poorly. Fishing boats would after a catch, only be rinsed very superfluously with pressurised seawater. No physical or chemical cleaning methods were employed. The rotation of fishing vessels were such, that often weeks passed before the same vessel would be used again. Vessels would not be rinsed again before the next trip. This created ideal conditions for substantial microbial build-up, which resulted in highly unsanitary conditions. Nothing had been done in the past, because no obvious health conditions resulted. It was believed that the level of contamination was not enough to cause significant problems and that thermal processing employed later during processing would eliminate the hazard.

Furthermore, the cleaning of boat holds had significant economic implications. Fishing boats are owned by small private companies or single owners, who catch fish on contract for the CSC. Cleaning of the boats are the responsibility of these owners. The labour and manpower costs for cleaning a boat over a season is substantial, and this influences the profitability of their business. Boat owners still believed that this was not really necessary. They were, therefore, very reluctant to pay this money unnecessarily, especially without getting anything tangible in return. It was, therefore, necessary to validate scientifically why the holds had to be cleaned.

Potential microbiological food safety hazards in canned seafood are mainly botulism, histamine poisoning and staphylococcal enterotoxin poisoning (Ababouch, 1992; Institute of Medicine, 1991). Botulism and staphylococcal enterotoxin poisoning are caused by under processing or post process contamination, whereas histamine contamination occurs on the fishing vessel or in the factory prior to sterilisation (Ababouch, 1992). Normally, in a canning operation, the growth of microbes prior to sterilisation do not pose a significant food safety risk, because the microbes and their toxins are normally destroyed by the extreme thermal conditions during sterilisation. The risk of histamine poisoning however, is significant because of its thermostability (Ababouch, 1992; Huss, 1994).

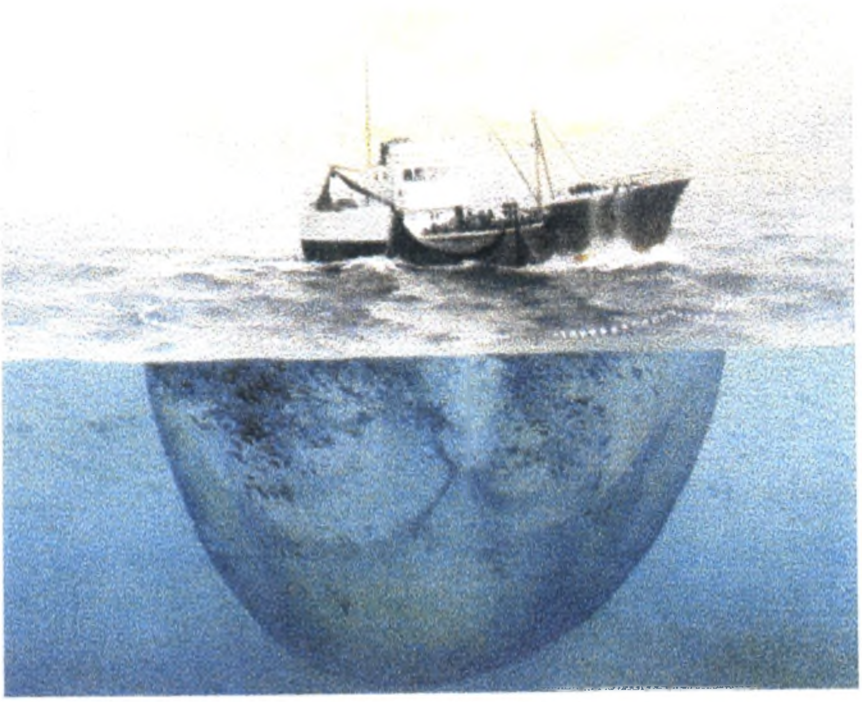

**Figure 1.** A typical purse-sein pilchard trawler in action.

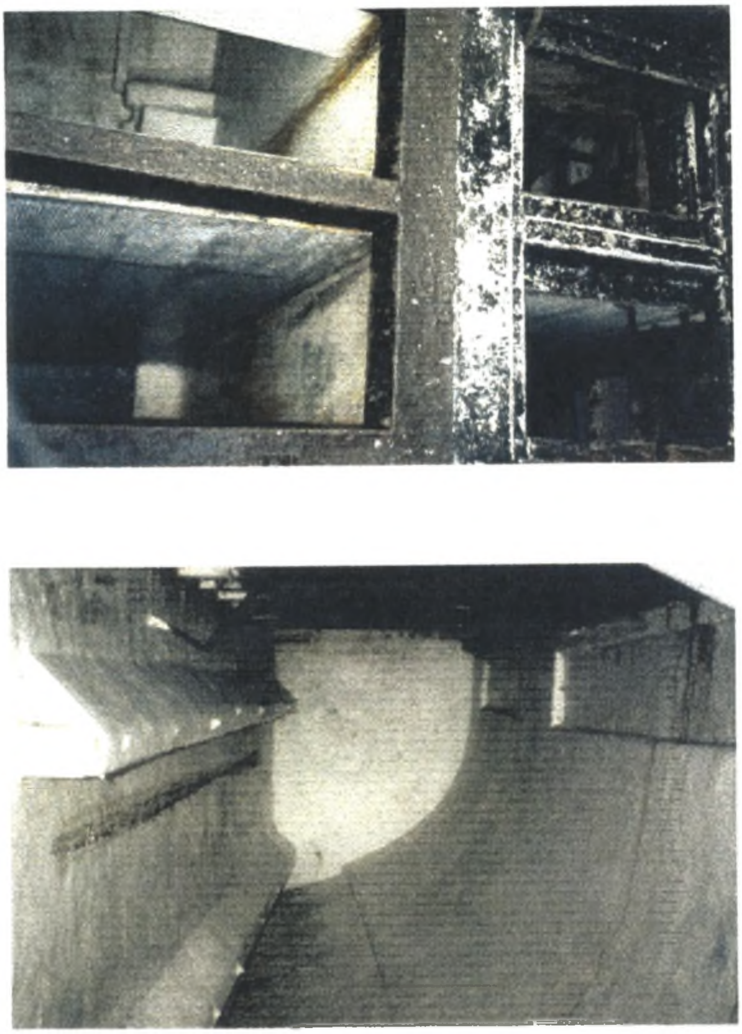

**Figure 2.** Outside and inside views of the holds of one of the pilchard boats in the case study company.

Histamine poisoning, also referred to as scombroid poisoning is caused by the consumption of foods that contain high levels of histamine. Histamine is a powerful biological active chemical, which can exert many responses within the body and may cause cutaneous, gastrointestinal or neurological symptoms. Normally histamine poisoning is not a severe long-term illness, but does cause severe acute uncomfort in patients (Shalaby, 1996). Histamine poisoning is normally associated with scombroid fish including tuna and mackerel. Other types of fish such as pilchards, sardine, herring, anchovies and shellfish are also implicated (Institute of Medicine, 1991).

Canned seafoods have been implicated in several outbreaks of seafood poisoning. A survey conducted in Great Britain showed that canned seafood accounted for 42% of the histamine poisoning outbreaks in 1976 - 1982 (Ababouch, 1992). Histamine is not indigenous to fish muscle and may accumulate in canned seafood between the stages of catching and sterilisation. This includes transport to the factory, storage on the vessel, storage in the factory and handling prior to sterilisation (Pan, 1985). It must be emphasised that once the histamine has been produced in the fish, the risk of causing disease is very high (Huss, 1994). Histamine is thermostable and does not break down during the canned fish sterilisation process. It may be found in the finished product even though the bacteria responsible for its accumulation have been inactivated (Ababouch, 1992; Huss, 1994). Certain studies have in fact, shown an increase in histamine during heat processing. This can be attributed to the degradation of fish by microbial enzymes during the come-up time to sterilisation, which can lead to an increase in the histamine concentration (Pan, 1985).

Histamine is formed during post mortem bacterial decarboxylation of the amino acid histidine as shown in Fig. 3. This reaction is catalysed by the bacterial enzyme histidine decarboxylase. The implicated fish contain large amounts of histidine, which serve as substrate for bacterial histidine decarboxylase. The main histamine-producing bacteria are members of the *Enterobacteriaceae*; *Vibrio*; *Clostridium*; and *Lactobacillus*. The most potent histamine producers however, are *Morganella morganii*, *Klebsiella pneumoniae* and *Hafnia alvei* (Huss, 1994).

The South African Bureau of Standards (SABS) specifies 20 mg per 100 g for any given sample and 10 mg per 100 g for the mean value of samples, as the maximum limit for histamine in seafood (Truter, 1998). The United States Food and Drug Administration (USFDA) specifies 50 mg per 100 g as the maximum toxic level and 5 mg per 100 g as the defect action level (USFDA, 1996). Many methods are available for detecting histamine in seafoods. These include: thin layer chromatography; colorimetry; fluorometry; gas-liquid chromatography; isotachphoresis; enzyme linked immunosorbent essay (ELISA); and high performance liquid chromatography (HPLC). In some cases it is more appropriate to determine histidine decarboxylase rather than to determine the exact histamine content. Methods include differential plating of histidine producing bacteria (Niven, 1981) and determination of gas formed by histamine-producing bacteria (Klausen & Huss, 1987). Studies have shown that under controlled

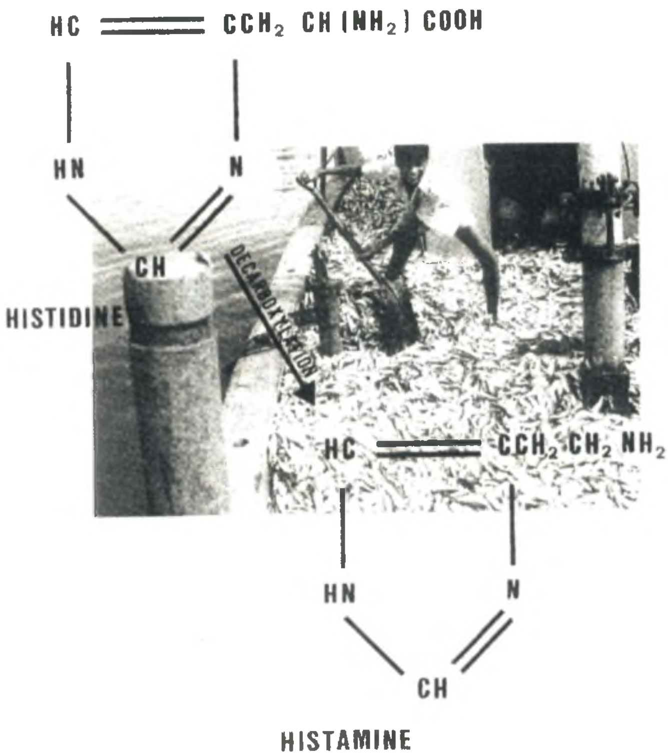


**Figure 3.** Chemical structure and formation of histamine (Pan, 1985).

conditions, 1 x $10^5$ histamine-producing bacteria will produce approximately 10 mg histamine per 100 g fish (Pan, 1985).

Histamine-producing bacteria are mesophilic organisms. However, several studies have shown that certain of these bacteria are capable of synthesising significant amounts of histamine in culture media or in fish under low storage conditions ranging from 0° – 8°C (Ababouch, 1992). Large amounts of histamine were formed by *M. morganii* at low temperatures (0° - 5°C) following storage at higher temperatures (10° - 25°C). It appears that even though bacterial growth ceases at 5°C or below, residual enzyme activity still continues, and histamine can be produced (Institute of Medicine, 1991; Huss, 1994). The contamination of contact surfaces by bacteria capable of producing histidine decarboxylase may, therefore, also be hazardous (Warne, 1985).

It was, therefore, clear that a possibility existed that, in the CSC, the unclean surfaces in the boat holds could contain high levels of histamine-producing bacteria, and consequently high levels of histidine decarboxylase. It is further possible that the new catch, which comes in contact with the unclean surfaces could be contaminated with unacceptable levels of histamine, which might pose a food safety risk. Apart from the condition of the holds, temperature profiles also indicated that histamine production is possible.

The first aim of this study was, therefore, to verify whether there is a histamine contamination risk at the step of cleaning the holds, in order to qualify its selection as a CCP. If it was verified as a CCP, the second aim was to introduce and implement measures to control this CCP. The third aim was then to set reference or target levels to monitor the efficacy of the controls.

## Materials and methods

*Case study company*

The case study company (CSC) produces canned fish, fish meal and fish body oil and utilises the services of nine separately owned purse-sein trawlers for fishing duties. These vessels are named A through I in this study. The company is situated on the South-Western coast of South Africa.

*Contact plate counts*

The first stage of this project was to conduct a general hygiene assessment of the holds of fishing vessels supplying the CSC, before any HACCP controls had been implemented. Contact plates with a 25 mm$^2$ surface were used for this purpose. The plates were supplied by 3M South Africa and filled with nutrient agar. Contact plate counts (CPC) were taken directly from random areas on the floors, walls and roofs of holds, respectively. Each of the four holds, of the nine vessels were sampled. Sampling took place within 2 h before vessels would sail for catching. Contact plates were incubated at 30°C ± 1°C for 48 h before colonies were counted visually. A total of 108 samples were collected. Sampling took place from May 1997 and ended in July 1998. As the sampling period was over such a long period, the influence of seasonal temperatures could be averaged out.

*Quantitative detection of histamine-producing bacteria (HPB)*

Control sample CPC is not an indicator of pathogenic activity and has very little food safety significance. For this reason, HPB counts were conducted to quantitatively screen the vessel holds, for the presence of HPB. The differential plating method of (Niven, 1981) was used. This method is based on the colour change of bromocresol purple, in response to a pH shift in the medium. This pH shift is dependent on the production of more alkaline histamine from histidine included in this media. This method was chosen above direct histamine analysis for a number of reasons. Firstly, too many variables exists in the origin of histamine if it is measured in the raw pilchard and even more if it was measured in the end-product (Pan,1985). Secondly, it was economically more feasible for this study and thirdly, a method was sought which could possibly in future, be used directly at the CSC without acquiring expensive equipment.

Wet swabs (dipped in neutralising buffer) were taken from random 5 $cm^2$ areas on the floor, wall and the roof of holds, respectively. Each of the four holds of the nine vessels were swabbed within 2 h before vessels would sail for catching. Swabs were kept at <5°C and transferred to histidine media within 24 h. Plates were incubated at 30°C ± 1°C for 48 h before colonies were visually counted. As was the case with CPC, a total of 108 samples were collected and sampling took place from May 1997 and ended in July 1998.

*Control sample*

A control sample was used to test the feasibility of the method of Niven (1981). A culture of *Morganella morganii*, was obtained as the control from Tygerberg Hospital, Francie van Zyl Drive, Parow Valley, Cape Town. The strain was cultured in brain heart infusion (BHI) broth for 24 h at 30°C ± 1°C. A dilution series was made and agars were inoculated with the control.

*Implementing HACCP controls*

The control measures implemented are described in the results and discussion section. Both experiments were then repeated under similar conditions, in order to measure the efficacy of the HACCP control measures. This took place from July 1998 to October 1998.

*Establishing critical limits*

It is very important that ecologically justified values are chosen as reference values in a HACCP study. Zero tolerances should not be arbitrarily set for pathogens without validation (Cloete, 1996; Huss 1994; Mossel, 1982). The microbiological reference value method of (Mossel, 1982) was used in this study to determine future target levels or reference values, for the control measures. It is important that the survey should take place only after strict control has been applied at all the factories, or in other words, after GMP / HACCP controls have been implemented. If this is not done, too many variables are created, results are too high, and setting a reference value may not be possible.

This method is based on the use of a distribution curve to set ecologically justified, quantifiable reference values. The method recommends that a survey is conducted at 10 factories where 10 samples from each factory are drawn. A distribution curve is obtained and prepared from the 100 samples. From this plot, the $95^{th}$ percentile ($\phi$) is computed; this is defined as the count not exceeded by 95% of the samples. A value somewhat above the $95^{th}$ percentile is set as a target value (n). Next, the maximum possible count to be expected (N) is set. The area between n and N is seen as the "alert" area. As a general rule, N is one log cycle higher than n and one log cycle lower than the Minimal Infectious Dose (MID).

For this study boats were used for the survey and not factories. Only 9 boats were available, but 12 samples were taken per boat giving a total of 108 data points. For the contact plate experiment, the four highest and four lowest samples were disregarded to give a final 100 data points. Distribution plots were prepared from these results to determine target levels for both data sets.

## Results and discussion

### *Contact plate counts*

Results of viable CPC during the initial hygiene assessment of boat holds, before the introduction of HACCP controls, are shown in Table 1. Although there is no set guideline for counts on this type of contact plate, the fact that 38 of the 108 samples showed counts of "too numerous to count" (TNTC) and only seven samples showed no growth, suggests that surfaces were highly contaminated. Boat A. appeared to be the "cleanest" as six of the 12 counts were below 100 cfu per area. Boat F appeared to be the "dirtiest" with 8 of the 12 counts being TNTC.

The floors of the hold were the "dirtiest", followed by the roofs, while the walls were the "cleanest" part of the holds. This can probably be attributed to the fact that whilst sampling, floors were very often wet with residual rinsing water or moisture from melted ice, creating ideal growth conditions. Walls, however could drain and dry, limiting growth. The high counts on roofs were probably due to them being constructed of wood, and thereby creating wet conditions.

**Table 1.** Viable contact plate counts (cfu) per 25 cm² in boat holds before HACCP.

| | Hold no. 1 | | | Hold no. 2 | | | Hold no. 3 | | | Hold no. 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Boat no.** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** |
| A | 775 | 250 | 225 | TNTC | 100 | TNTC | TNTC | 80 | 33 | No Growth | No Growth | No Growth |
| B | 70 | 55 | 700 | TNTC | 275 | No Growth | 450 | 550 | 150 | TNTC | 450 | TNTC |
| C | 800 | No Growth | 575 | TNTC | TNTC | 300 | 200 | No Growth | 875 | 425 | 80 | 850 |
| D | 925 | 30 | 550 | TNTC | 675 | TNTC | 550 | TNTC | 450 | TNTC | 775 | TNTC |
| E | TNTC | 675 | TNTC | TNTC | TNTC | TNTC | 425 | 100 | TNTC | 800 | 125 | 550 |
| F | TNTC | TNTC | 150 | 750 | 875 | TNTC | 975 | TNTC | TNTC | TNTC | TNTC | TNTC |
| G | 450 | 125 | No Growth | 275 | TNTC | 47 | 325 | 100 | 450 | 1075 | 250 | 975 |
| H | 325 | TNTC | TNTC | 800 | 300 | TNTC | TNTC | 1025 | TNTC | 500 | TNTC | TNTC |
| I | 700 | 200 | TNTC | 675 | TNTC | 275 | 400 | 750 | TNTC | 725 | 48 | 325 |

TNTC = too numerous to count (> log 4)
No Growth = zero counts

**Table 2.** Histamine producing organisms per 5 cm² in boat holds before HACCP.

| | Hold no. 1 | | | Hold no. 2 | | | Hold no. 3 | | | Hold no. 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Boat no.** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** |
| A | 2 | No Growth | 10 | 30 | No Growth | No Growth | 200 | No Growth | No Growth | No Growth | 9 | No Growth |
| B | No Growth | No Growth | 110 | 3 | No Growth | No Growth | No Growth | No Growth | No Growth | 312 | No Growth | No Growth |
| C | 600 | No Growth | No Growth | No Growth | 12 | No Growth | 20 | No Growth | 120 | 1240 | No Growth | 32 |
| D | 6 | No Growth | No Growth | 13 | No Growth | No Growth | No Growth | No Growth | No Growth | 60 | No Growth | No Growth |
| E | 600 | No Growth | 60 | 12 | No Growth | 2 | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth |
| F | 1000 | No Growth | No Growth | 4 | No Growth | No Growth | 7 | No Growth | 3 | 850 | No Growth | No Growth |
| G | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | 3 |
| H | 9 | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | 510 | No Growth | No Growth |
| I | No Growth | No Growth | 8 | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | 2 |

*Quantitative detection of histamine-producing bacteria (HPB)*

The results obtained from the HPB counts are shown in Table 2. It was worrying to find that all boats showed HPB activity in at least one hold. Boat G appeared to be the least contaminated with 11 of the 12 samples showing no counts. Boats A, C and F were the most contaminated with 5 out of 12 samples showing counts. As was the case with the CPC results, the floors of the hold appeared to be more contaminated with HPB, followed by the roofs and the walls.

*Control sample*

Growth of the *M morganii* control strain was detected up to the 1 x $10^{-8}$ dilution and uninoculated controls showed no growth on the histidine medium. This clearly validates the feasibility of the method. The results are shown in Table 3 and Fig. 4.

*Implementing HACCP controls*

It was quite clear from the introduction section that histamine is a significant hazard in canned pilchards. This, together with the results mentioned above, suggests that a realistic food safety hazard does exist, which requires immediate control. The control measure to prevent the formation of HPB in boat holds is simply the thorough cleaning and sanitizing of holds after emptying of holds. Holds had to be clean enough, not only to eliminate HPB, but also histidine decarboxylase enzymes. A master cleaning schedule, as shown in Table 4 was drawn up which summarises the control measures.

The results of viable CPC after the introduction of the HACCP related control measures are shown in Table 5. The improvement in viable CPC counts are graphically illustrated in Fig. 5. There was a definite strong shift from the TNTC end of the graph, to the no-growth end. This shows that the cleaning methods employed were effective in reducing microbial build-up.

Results of HPB counts after the introduction of HACCP are shown in Table 6. The improvement in HPB counts are graphically illustrated in Fig. 6. Similarly to the viable CPC, there was a marked improvement in the reduction of HPB after the implementation of HACCP controls. After controls were implemented, 95% of the samples showed no growth. It was, therefore, clear that the cleaning method given in Table 4 is effective in reducing the potential food safety hazard of histamine contamination. In some isolated instances, CPC and HPB increased after implementing HACCP controls. This can only be explained by the fact that it was not always possible to clean all areas equally well, even after HACCP had been implemented. When these controls are applied regularly, the build-up should be reduced.

After HACCP controls were implemented, Boats B and G were the "cleanest" with eight out of 12 samples showing no CPC growth and both boats showing no HPB activity. The cleanliness of Boat B can be attributed to the fact that it was constructed of glass-fiber while the others were constructed of wood.

**Table 3.** Testing of a control histidine medium with *M. morganii*.

| Dilution | Colony count |
|---|---|
| $1x10^{-5}$ | TNTC* |
| $1x10^{-6}$ | TNTC |
| $1x10^{-7}$ | 20 |
| $1x10^{-8}$ | 5 |
| Uninoculated control | No growth |

*TNTC = Too numerous to count.


**Figure 4.** Actual growth of *M. morganii* on the histidine medium.

**Table 4:** Master cleaning schedule for pilchard boats.

| Task | Method | Chemical | Chemical ratio | Assigned to | Responsible | Record | Inspector |
|---|---|---|---|---|---|---|---|
| ***ROUTINE CLEANING – To be done within 2 h after off-loading*** | | | | | | | |
| Remove loose fish on deck | Manually and or nylon broom | | | Deck hand 1 | Skipper | Daily cleaning checklist | Shore skipper |
| Remove oil/diesel spills on deck | Squeegee | Hygen F29[1] | 40 ml per l | Deck hand 1 | | | |
| Remove loose fish in holds | Manually | | | Deck hand 2 | | | |
| Apply foam in holds | Use foam gun, leave for 15 min | Hygen F29 | 40 ml per l, 3-5 l per 4 holds | Deck hand 3 | | | |
| Scrub roofs walls and floors | Nylon brushes, nylon brooms, scrub for 10 min per hold | | | Deck hands 2, 3 and 4 | | | |
| Rinse | High pressure nozzle, 5 min | Potable water | | Deck hand 4 | | | |
| Apply sanitiser | Sanitiser gun | Hygen Q45[2] | 10 ml per l, total of 1 l per 4 holds | Deck hand 1 | | | |
| ***ROUTINE PRE-LOAD RINSING – To be done within 2 h of ice-loading*** | | | | | | | |
| Rinse | High pressure nozzle, 5 min | Potable water | | Deck hand 1 | Skipper | Daily cleaning checklist | Shore skipper |
| Apply sanitiser | Sanitiser gun | Hygen Q45 | 10 ml per l, total of 1 l per 4 holds | Deck hand 2 | | | |
| ***MONTHLY DEEP CLEANING – To be done once per month*** | | | | | | | |
| Scrub deck | Nylon broom, squeegee, 1 h | Hygen F29 | 20 ml per l | Deck hand 1 | Skipper | Monthly cleaning checklist, CPC and HBP report and boat cleaning schedule | Shore skipper |
| Apply foam | Foam gun | Hygen F29 | 40 ml per l, 3.5 l per 4 holds | Deck hand 3 | | | |
| Scrub roof walls and floors | Nylon brushes, nylon broom, 1 h per hold | | | Deck hands 2, 3 and 4 | | | |
| Rinse | High pressure nozzle, 10 min | Potable water | | Deck hand 4 | | | |
| Apply sanitiser | Sanitiser gun | Hygen Q45 | 10 ml per l, total of 1 l per 4 holds | Deck hand 1 | | | |

1. Active ingredient, sodium hydroxide (3.5% m/v)
2. Active ingredient, available chlorine (2.5% m/v)

**Table 5.** Viable contact plate counts (cfu) per 25 cm² in boat holds after HACCP.

| | Hold no. 1 | | | Hold no. 2 | | | Hold no. 3 | | | Hold no. 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boat no. | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** |
| A | 25 | 41 | No Growth | 550 | 23 | 550 | 875 | No Growth | 40 | 550 | 20 | 200 |
| B | No Growth | 4 | No Growth | 150 | No Growth | No Growth | 11 | 4 | No Growth | No Growth | No Growth | No Growth |
| C | No Growth | No Growth | 56 | TNTC | 125 | 100 | 150 | 125 | 44 | No Growth | No Growth | 40 |
| D | 150 | 40 | 150 | 60 | 150 | 6 | No Growth | No Growth | No Growth | 150 | 16 | 150 |
| E | 40 | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | 23 | No Growth | No Growth | No Growth | No Growth |
| F | TNTC | 175 | 43 | 275 | 325 | 150 | 450 | 200 | 8 | 675 | 300 | 80 |
| G | 8 | No Growth | No Growth | 225 | No Growth | 200 | No Growth | No Growth | 675 | No Growth | No Growth | No Growth |
| H | 475 | TNTC | 400 | 11 | 525 | No Growth | 40 | TNTC | 32 | TNTC | 125 | 125 |
| I | No Growth | No Growth | 18 | 2 | 10 | 6 | 3 | 24 | 10 | 6 | 4 | 24 |

**Table 6.** Histamine producing organisms per 5 cm² in boat holds after HACCP.

| | Hold no. 1 | | | Hold no. 2 | | | Hold no. 3 | | | Hold no. 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Boat no.** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** | **Floor** | **Wall** | **Roof** |
| A | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | 5 | No Growth | No Growth | No Growth | No Growth | No Growth |
| B | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth |
| C | 150 | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | 46 | 9 | No Growth |
| D | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth |
| E | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth |
| F | 30 | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth |
| G | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth |
| H | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth |
| I | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth | No Growth |

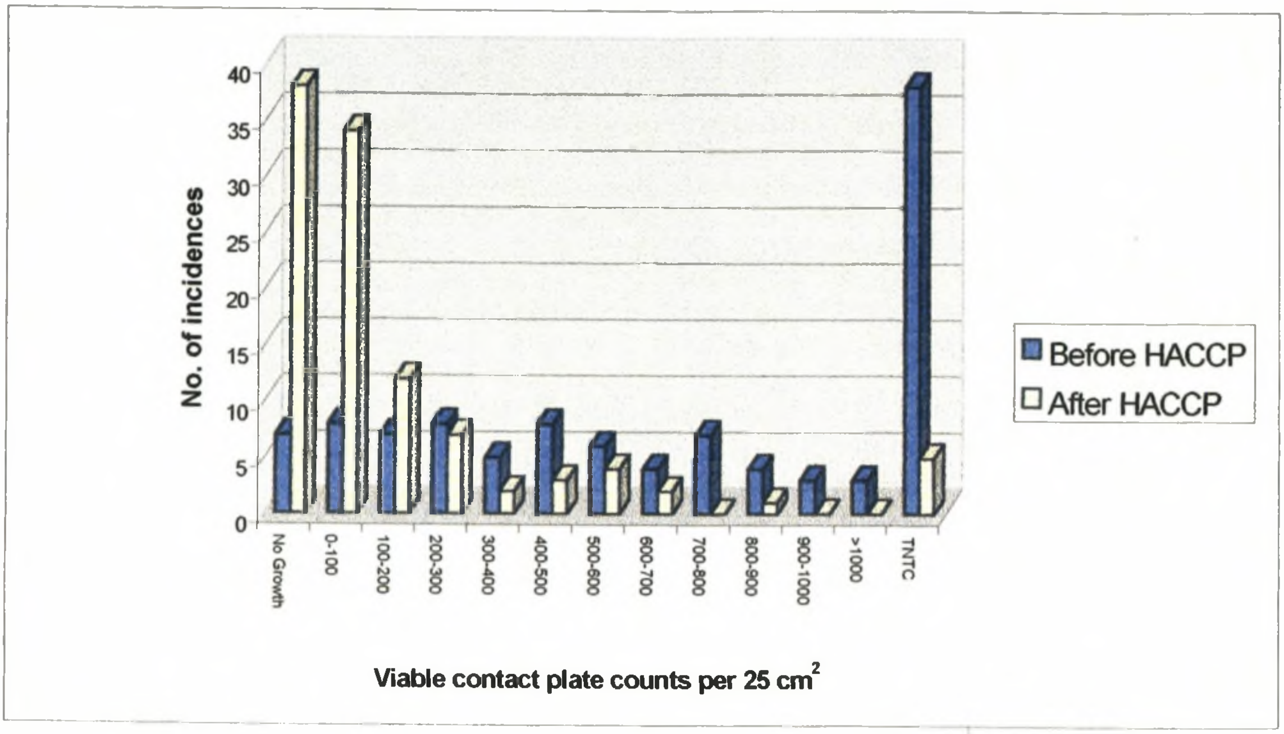


**Figure 5.** Improvement of viable contact plate counts in boat holds after HACCP.

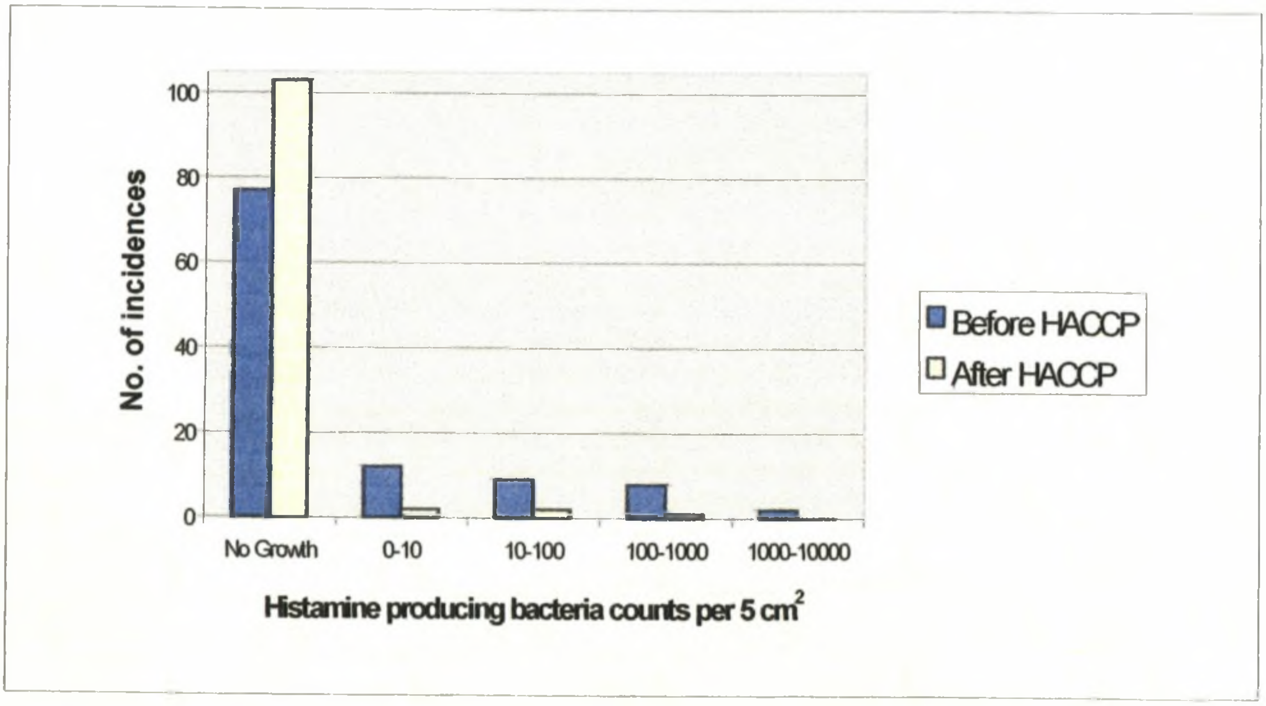


**Figure 6.** Improvement in histamine producing bacteria counts in boat holds after HACCP.

This shows that fibreglass is a lot easier to clean than wood. Boat F seemed to be the "dirtiest" in terms of CPC and boat C the "most contaminated" in terms of HPB.

*Establishing critical limits*

After control measures were implemented, the next step was to set achievable target levels. A frequency distribution graph of viable CPC, is shown in Fig. 7. The 95th percentile ($\phi$), intercepted the x-axis at log 3.5, n was theoretically set at log 4 and N at log 5. However, it should be kept in mind that a 25 $cm^2$ CPC can only reach log 4 before it effectively becomes TNTC. The target level for the CPC, for measuring cleanliness was therefore set at $\phi$. It should be stressed, however, that this CPC is only a very rough indication of cleanliness, and should be used together with the HPB count.

A frequency distribution graph of HPB, is shown in Fig. 8. It has been established that the maximum infectious dose (MID) in terms of toxicity for HPB in fish flesh is log 5. Since there is no clear relationship between the MID in fish flesh and contact surfaces, the level of log 5 was chosen to be safe. The 95th percentile ($\phi$), intercepted the x-axis at log 1. The N value was set at log 4, one log cycle below the MID and n was set at log 3, one log cycle below N. It can, therefore, be concluded that the target level should be set at log 3 and the critical limit at log 5.

## Recommendations

When practically applying the above control measures and limits, it should be kept in mind that a boat cannot wait for two days for microbial results, before sailing. Therefore, microbial monitoring should only be done once a month after deep cleaning, to verify the controls. The more wood present in the boat holds, the more thorough and more often, they should be cleaned.

The routine day-to-day monitoring should take place in the form of thorough visual inspection of boat holds before preparation for trips. For this purpose a boat inspector needs to be appointed and trained appropriately. If the vessel is found to be unsatisfactory, it should be recleaned. If, during a monthly audit, levels of log 3 for HPB or log 3.5 for CPC are found, the boat owner must either reclean the holds or consider more hygienic maintenance procedures. If counts of log 5 are found for HPB, the boat should not be considered for fishing until the owner can prove that effective corrective action has been taken. Boat owners should, if possible, in the long term, eliminate wood from holds and replace it with other materials such as fibreglass.

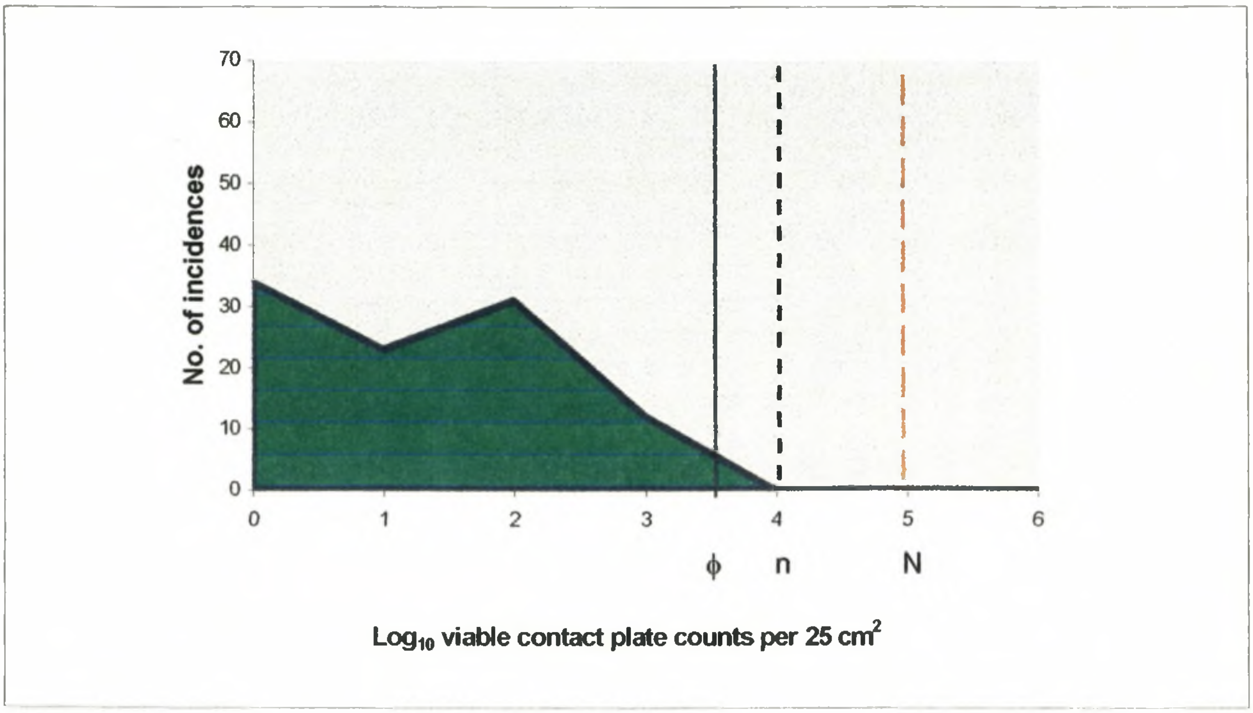


**Figure 7.** Distribution plot for calculating target levels for contact plate counts in boat holds.

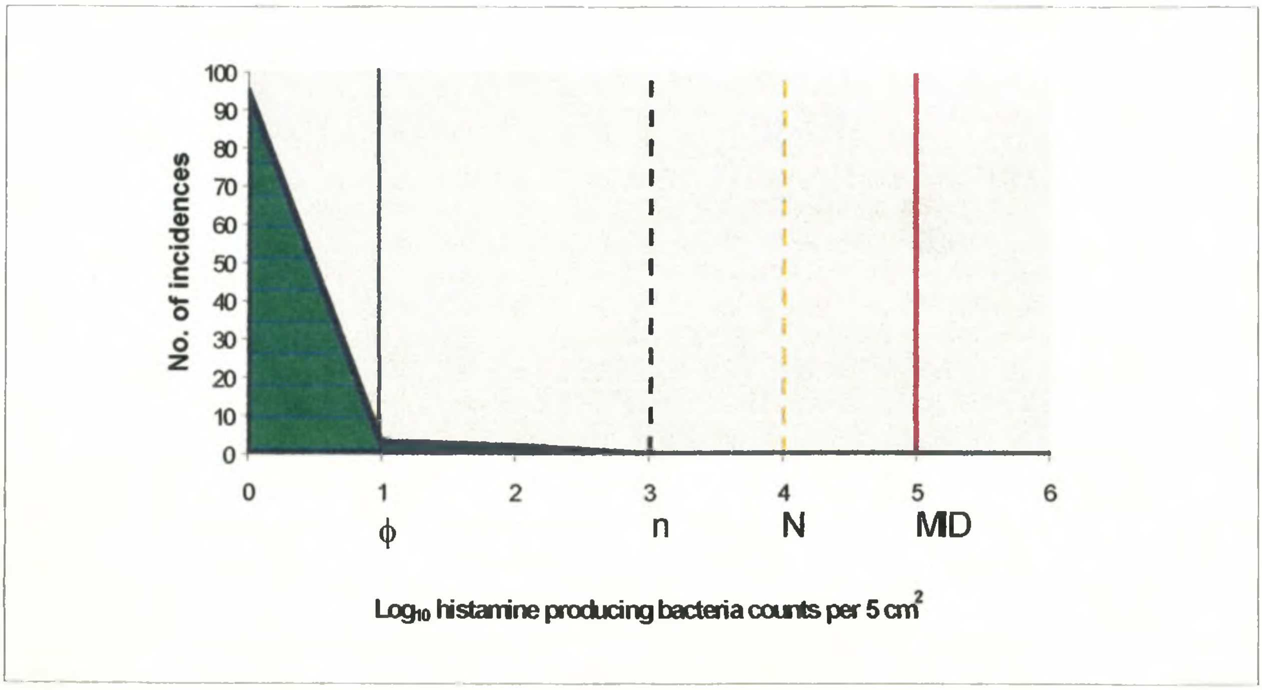


**Figure 8.** Distribution plot for calculating target levels for histamine producing bacteria in boat holds.

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# CHAPTER 6

# CONDUCTING A HACCP VERIFICATION STUDY AT A FRESH CAPE HAKE PROCESSING OPERATION

## Abstract

A crucial step in the HACCP implementation process is establishing verification procedures. Fishing companies worldwide and in South Africa are notorious for not paying enough attention to verifying their HACCP plans. For this reason, a study was conducted in a South African fishing company to show how the control of an important food safety hazard can be verified. A Cape hake trawling and processing company was used in the case study. Microbial growth due to poor temperature control was selected as the hazard. The verification performed was to log times and temperatures during processing to ascertain whether temperature control was adequate to prevent the hazard. Logging took place during all stages of processing from catching and holding in the on-board stocker pond, through to selling on a fish market in Vitoria, Spain. Results of the study showed that the temperature of the fish was reduced to below the critical limit of 3°C within 6 h and that it was kept under the critical limit during all stages of the process. This verified that the hazard of microbial growth was controlled adequately.

## Introduction

Once a HACCP plan has been designed, it should be correctly verified (Mitchell, 1992) as verification is fundamental to the successful implementation of HACCP. The purpose of verification is to provide a level of confidence that the plan is based on solid scientific principles, that the plan is adequate to control the hazards associated with the product and process, and that the plan is being implemented on the factory floor (USFDA, 1996). Verification is formally defined as the application of methods, procedures, tests and other evaluations, in addition to monitoring, to determine compliance with the HACCP plan (SABS, 1999).

The elements of verification are validation of the HACCP plan, verification of hazards, verification of CCP's, verification of the HACCP system through audits, microbiological end-product testing and surveys from the marketplace (for example customer feedback) for unexpected health or spoilage problems (USFDA, 1996; FAO & WHO, 1997).

Confusion often exists between the terms "validation" and "verification". Validation requires substantiating that the HACCP plan, if implemented correctly, is sufficient to control the food safety hazards that are likely to occur in the particular product and process. Validation occurs before the plan is actually implemented (USFDA, 1996). In chapter 5 of this thesis it is explained how a CCP was validated before the controls were implemented. Verification on the other hand happens after the plan has been implemented and makes sure or "double checks" that the hazards are under control and is additional to routine monitoring (SABS, 1999).

For this study, a HACCP verification study was conducted on a Cape hake trawling and processing company. The most important hazard in fresh trawled white fish, as shown in Chapter 4 of this thesis, is microbial growth. The control measures are adequate chilling and chill-storage of the fish. The recommended critical limits for fish destined for the European Union (EU), is between 3° and –2°C during all stages of storage and distribution (Truter, 1998). It should be kept in mind that non-pathogenic spoilage organisms will grow before pathogens, which means that fish will be organoleptically offensive before pathogens will be present at dangerous levels (Huss, 1994). Pathogenic activity will only occur at conditions exceeding 10°C for 6 h (USFDA, 1996). The lower limit of –2°C on the other hand, if exceeded, will also not compromise food safety. It is, however, important to stay above –2°C because lower temperatures will mean that the fish can no longer be classified as "fresh" but rather as "frozen". Sub –2°C temperatures may also cause the formation of large ice crystals in fish flesh, which, in turn may damage the flesh structure and result in flavour and texture loss (Huss, 1994). The point is that the "critical limits" are strictly not "critical" in terms of food safety. Nevertheless for this study 3° to –2°C were considered as the critical limits.

Because of the many complex time/temperature variables, the European Union (EU) does not specify a time/temperature limit for the fish to reach these critical limits after catching. The (USFDA, 1996) does not specify a time to reach the critical limits for white fish. Limits are, however, given for Mollusks as: 14 h to reach 40°F (4.4°C); and for Scombroid fish as: 6 h to reach 50°F (10°C). This means that if the fish temperature is brought down to these limits in an adequate time, and kept there during all processing stages, the hazard of microbial growth can be verified as being under control.

Verification is one of the more complex HACCP principles. Subsequently, this step is often only done very loosely or forgotten altogether (USFDA, 1996). This tendency is also found in the South African fishing industry. Skill levels are relatively low and companies struggle to implement the basics of HACCP, let alone understand how to verify whether the system is correct (Uys, 1999). Based on these limitations, the aim of this study was to conduct a study on a Cape hake processing company to verify whether the hazard of microbial growth is controlled adequately.

## Materials and methods

### *Case study company*

The case study company (CSC) trawls and processes wholesale fish and operates from the Cape Town harbour. Work was conducted on a 46 meter, 38 crew, stern trawler, which was built in 1971. Photographs of the activities at the CSC are shown in Fig. 1. The main target species was Cape hake (*Merluccius capensis or Merluccius paradoxus*). The target market was mainly Spain as well as other European Union countries. The product selected for the study was head-on gutted Cape hake, which is sold wholesale, and packed in insulated polystyrene boxes together with a 600 ml ice in plastic pack as chilling medium. Size three (360-420 mm) and size four hakes

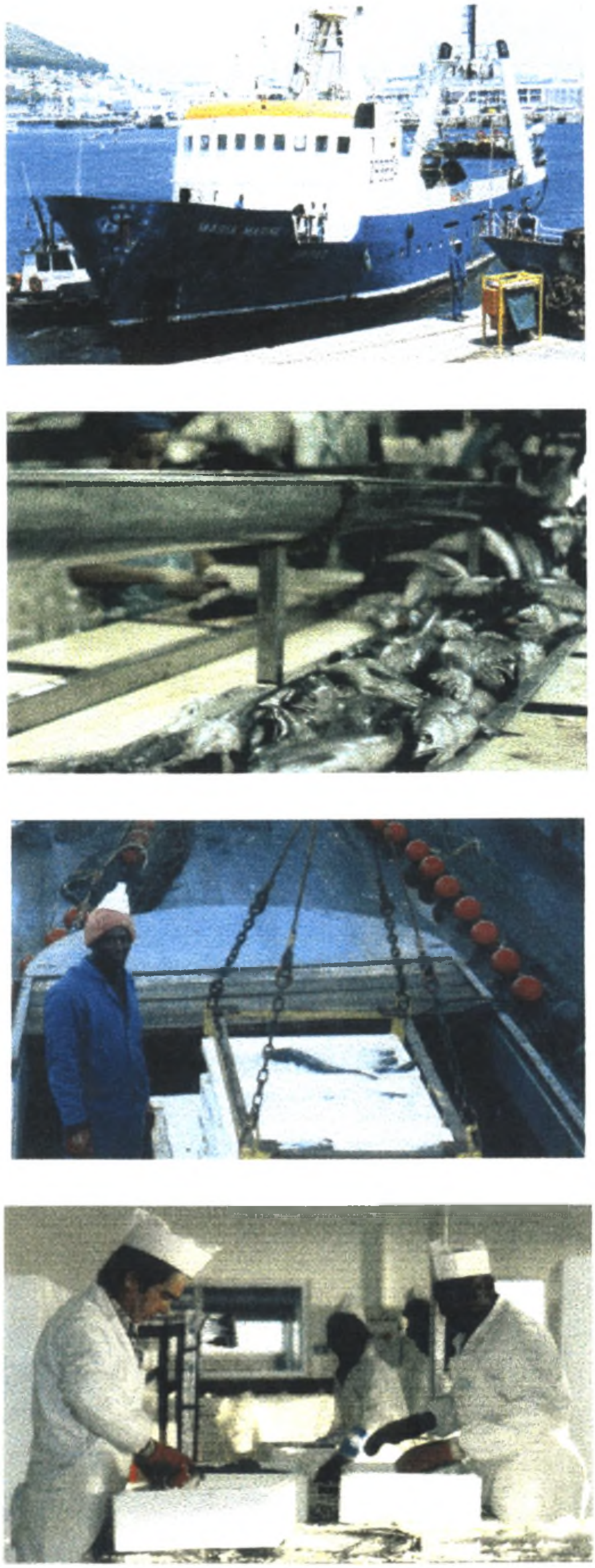

Figure 1. Photographs showing processing activities at the case study company and vessel.

(420-480 mm) were used in the study. Counts of fish per box ranged from four to seven and the target final product nett weight was 20 kg.

*On-board data logging (stocker pond)*

A calibrated eight channel Squirrel data logger (Grant 1200 series, Monitoring Control Laboratories) with a temperature range of –50° to + 100°C was used with K–type thermocouples and compensation cables. The logger was set to record all eight channels with 30 min intervals. Logging took place from 10 a.m. on 10-4-98 and ended on 4 p.m. on 14-4-98. Three thermocouples were used to record temperatures in the stocker pond at different positions. The stocker ponds are those areas of the trawler, which are designed as a holding area between catching and on-board processing. The channel-1 thermocouple was placed at the bottom of the front wall of the portside stocker pond. Being at the bottom, this largely measured temperature conditions below the fish line. The channel-2 and -3 thermocouples were placed on the inside and outside walls of the portside stocker pond, above the normal fish line. During the trip, activities at the stocker pond were closely observed in order to get an idea of the rotation tempo of fish through the stocker pond.

*On-board data logging (chill room)*

The channel-4 thermocouple of the Squirrel data logger was placed on the roof, in the center of the fish chill room. This was theoretically the warmest place to measure air temperature in the chill room. Channels -5, -6 and -7 were connected to spiked stainless steel temperature probes. These were inserted into three different fish, at three different places in the chill rooms. The probes were inserted 3 cm deep, behind the dorsal fin of the center, topmost fish in a bin. Crates at the bottom starboard, top starboard and bottom portside were used. The channel -8 thermocouple was placed on deck, in order to monitor the outside air temperature.

*Data logging from off-loading to pre-transport chilling*

Two calibrated individual cable free, Tinytag data loggers (Gemini data loggers, UK), with spiked stainless steel probes, with a range of -40° to +75°C were used. As soon as the trawler had docked and the fish bins off-loaded, the loggers were inserted into two different fish in two different bins. Logging started at 11.30 a.m. on 25-5-98 and ended at 10.20 a.m. on 26-5-98. The first probe was inserted in the bottom center fish of its crate and the second in the top left-hand corner. The loggers were set to record with 2-min intervals. Recording took place from off loading throughout pre-packing, chilling, rinsing, final packaging into insulated cooled boxes to the pre-transport chilling stages.

*Data logging from pre-transport chilling to selling*

Two calibrated individual 35 mm, capsuled cable free loggers (Gemini Data loggers ,UK), were used with a range of -40°C to +75°C. A polystyrene box packed with fish was intercepted on route while being packed into the truck destined for the airport. The loggers were inserted and the box was resealed. One logger was placed in the centermost part of the polystyrene box and the other was placed on top of the ice. The loggers were set to record with 10 min intervals. Recording covered the following stages: truck loading; a drive to Cape Town International Airport; storage at the airport chiller at 7°C; a flight to Vitoria, Spain via Lagos, Nigeria; a truck drive to a fish market; and subsequent unloading stages. The probe was retrieved after the fish had been placed on the market floor, and the loggers couriered back to Cape Town. Logging took place from 11.41 a.m. on 14-7-98 to 16.26 p.m. on 16-7-98.

*Combined profile for the entire process*

The results from all the individual profiles were pooled to compile a combined time/temperature profile for the entire fishing process from catching to selling. Hourly temperature readings of a single fish were taken with a handheld thermometer, as it entered the stocker pond and as it proceeded through the subsequent stages of sorting gutting cleaning and packing into bins. Hourly readings were taken during chilling from the Squirrel logger's channel-6 reading (internal temperature, bottom port). For the remainder of the profile, readings from Fig. 4. (crate 2) and Fig. 5. were used.

## Results and discussion

*On-board data logging (stocker pond)*

The time/temperature profiles (Fig. 2) were plotted from the data obtained and the results generated by the three thermocouples, which were placed in the stocker ponds. Data at 30 min intervals for 24 h were used. (10.00 a.m to 10.00 a.m). It was found that the temperatures varied between 9° and 14°C during this period. It is evident from the profile that the temperatures were higher, fluctuated more, and varied more in the different points of the stocker pond during the warmer daytime temperatures than in the cooler night. As expected, the temperature at the bottom of the stocker pond, below the fish level, was slightly colder than the centre and top. During the trip it was observed, that the production system on board was efficient enough for a fish not to remain in the stocker pond for more than 3 h. The subsequent steps of sorting, gutting, and cleaning did not take longer than 1 h. The outside air temperatures are also shown as a footnote in Fig. 2, but did not drastically influence stocker pond or chilling activities.

*On-board data logging (chill room)*

Time/temperature profiles (Fig.3) were plotted from data generated by the thermocouples of the four channels of the data logger, which were placed inside the chill room. Temperature data at 30 min intervals for 56 h was used. The data showed that the air temperature at the roof of the chill room fluctuated between 4.7° and -3°C.

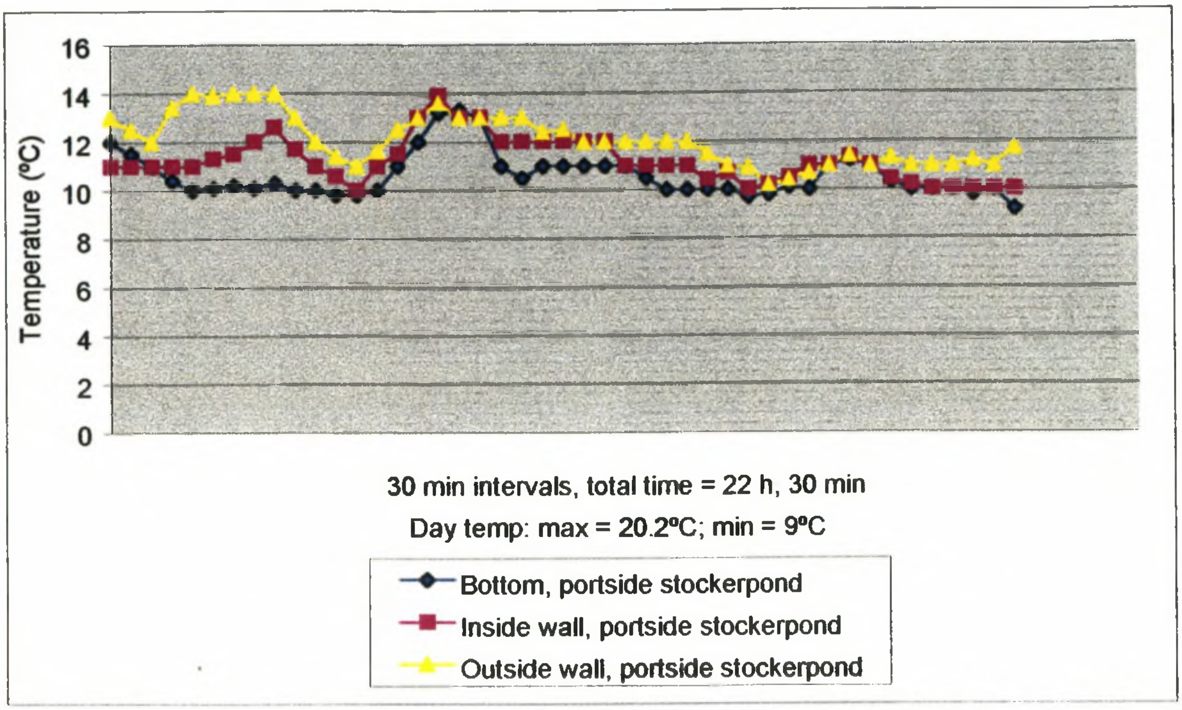


**Figure 2.** Time/temperature profile of whole gutted Cape hake in a stocker pond.

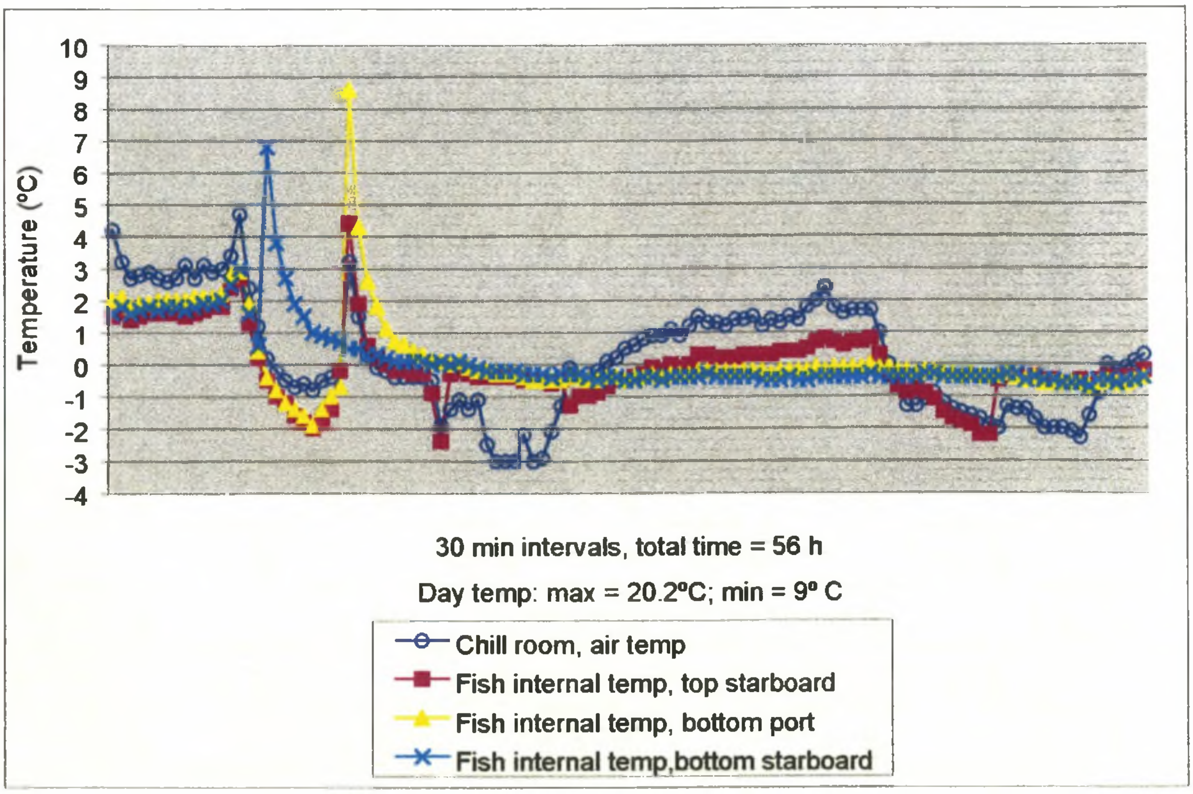


**Figure 3.** Time/temperature profile of whole gutted Cape hake during on-board chilling.

The abnormal peaks could be attributed to holds being opened and new batches of "warm" fish being packed into the chill room. For practical reasons the internal fish probes were not inserted into fish immediately after the logger was initiated. The fish room first had to fill up to where the probes where situated. After 8 h of logging the first probe was inserted into its fish and after 13 h the other two were inserted. Before this stage the probes were only recording chill room air temperatures. Channel-7, the internal fish probe at the starboard side of the bottom of the chill room, was inserted into the fish first and showed a significant peak on the profile. The internal temperature of the fish decreased from 6.8° to below 1°C in 3 h and to 0.1°C in 7 h after which it stabilised to between 0° and -1°C. The internal fish probes of channels-5 and -6 were inserted next at the top starboard and the bottom port side, respectively. The temperature in the top starboard probe decreased from 4.4° to below 1°C in 90 min.

An interesting observation was that the time/temperature profile slipped to below the -2°C critical limit on two occasions. This can be explained by the fact that the bin in which the probe was situated was very close to the chiller fan. The two temperature drops happened during the routine chilling cycles. The internal temperature at the bottom port side, decreased from 8.6° to below 1°C in 150 min, after which it stabilised at between 0° and -1°C.

*Data logging from off-loading to pre-transport chilling*

The temperature data was logged at 2 min intervals, and the time/temperature profile of 20 min intervals is shown in Fig. 4. Temperatures were found to fluctuate between 1.1° and -2.5°C. In this study no dramatic temperature rises occurred at any stage, which indicated that production was well organised and efficient. Of concern however, was the fact that temperatures were lower than the critical limit of -2°C during pre-packaging chilling. Although this had no food safety implications, exposure to such low temperatures might have compromised quality factors such as texture and taste.

*Data logging from pre-transport chilling to selling*

Data was logged at 10 min intervals, and the time/temperature profile of 20 min intervals is shown in Fig. 5. The data from one logger was used. The time/temperature profile was found to be generally very stable. Temperature was kept close to 1°C at all stages. However, temperatures were found to slowly increase during post-flight off loading and transport stages. Even though it was high summer in Spain, the critical limit of 3°C was not exceeded.

*Combined profile for the entire process*

The combined time/temperature profile for the entire process is shown in Fig. 6. Of note is the fact that a fish took 6 h to reach the critical limit of 3°C. This is well within the recommended guidelines of the USFDA (USFDA, 1996). Furthermore, during the entire chain the temperature never exceeded 2°C, let alone 3°C. The time from

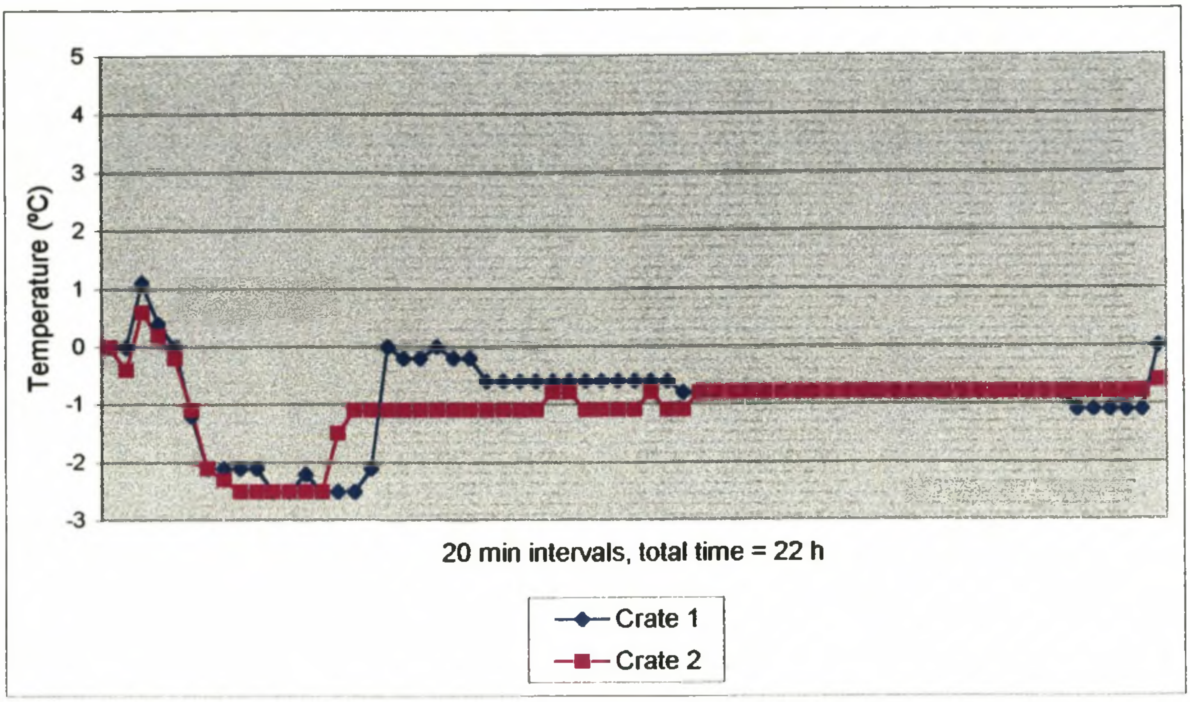


**Figure 4.** Time/temperature profile of whole gutted Cape hake from boat off-loading to pre-transport chilling.

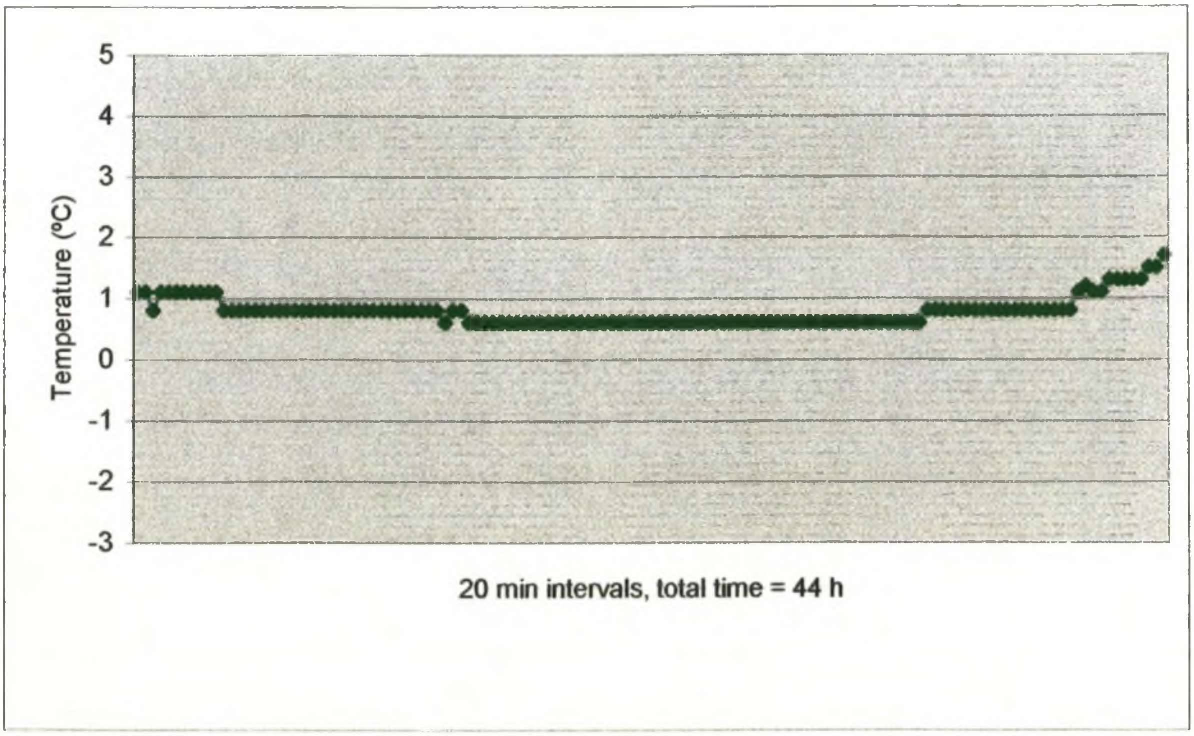


**Figure 5.** Time/temperature profile of whole gutted Cape hake from pre-transport chilling to selling.

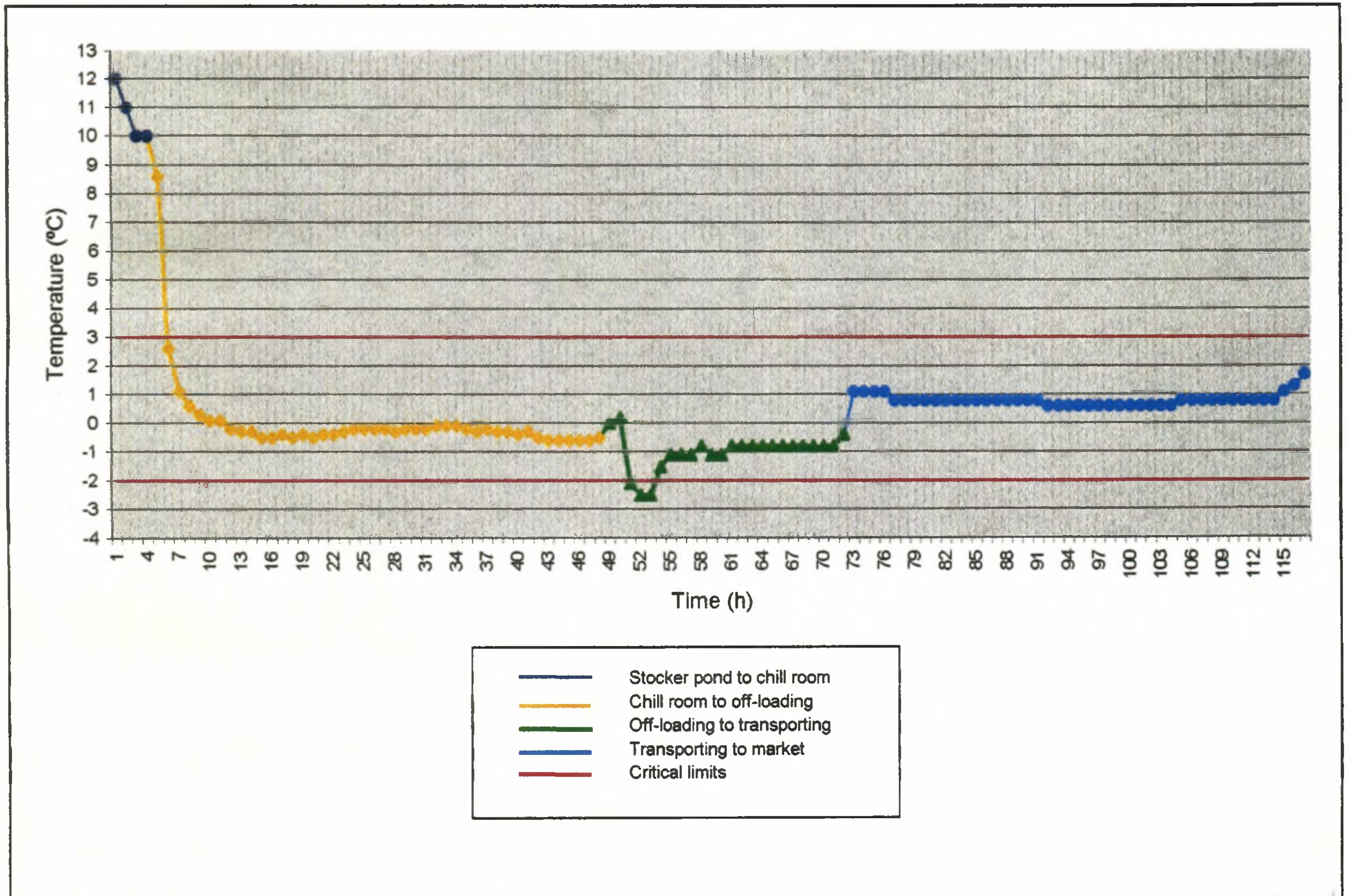


**Figure 6.** Complete time/temperature profile of a whole gutted Cape Hake through all stages from catching to selling.

catching to selling is 117 h or just under 5 d. From this study it is clear that food safety is not compromised. The hazard of microbial growth can, therefore, be verified as being under control. It should be kept in mind however, that this study was only a snapshot. During this study no difficulties such as storms at sea, power failures or flight delays, were experienced and it must be taken into account that HACCP is not normally compromised when things are normal, but rather during extraordinary circumstances. Furthermore, the verification in this study only covered the hazard of microbial growth. Other verification studies such as microbial swabbing could be done to verify that cross contamination is under control.

**Recommendations**

From the data obtained during this study, it is clear that the CSC should continue the efficient manner of temperature control throughout the process, but should ensure that sound corrective action plans are on hand in the case of an emergency. The area of on-board chilling and pre-packing chilling requires attention, because it was shown that temperatures were below the minimum critical limit of -2°C. This does not influence the safety of the fish, but may have an influence on the quality aspects such as flavour and texture loss.

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# CHAPTER 7

# GENERAL DISCUSSION AND CONCLUSIONS

South African fish processing companies must implement HACCP systems, which are both technically correct, based on good sound science and practically actionable on the factory floor. If this is not done and companies perform half hearted HACCP attempts, they will only succeed in exposing themselves. The fact that the fishing industry is South Africa's ambassador in the international food safety arena may mean that such negative exposure might do a great deal of damage, not only to the fishing, but to the entire food industry.

This study was therefore aimed at using the fishing industry as an example of implementing technically correct practical HACCP systems. In this study it was showed how HACCP can successfully be applied to fish canning and fresh fish processing operations. The models developed in the study only represent a small part of the total HACCP programme and should be seen as a guide in understanding the thinking process behind interpreting the seven Codex Alimentarius HACCP principles. The models from this study can be used as a starting point from which the 12 HACCP implementation steps can be followed.

Specific areas where fish processors in South Africa lack understanding are to correctly select, validate and verify CCPs, as well as to set ecologically justified limits to monitor these critical control points. This study, therefore, highlighted these aspects by means of case studies at pilchard and hake processing companies. The hard work however, is to customise and streamline the system for each individual company. This has not, and can not be addressed in such a study and is the sole responsibility of the company itself.

Theoretically, the HACCP system and its application in the South African fishing industry is sound, but practically there are a great deal of stumbling blocks which have to be overcome before HACCP can work as it was designed to do.

The first problem is that many fishing companies fail to realise that HACCP is not just a once off and superficial paper exercise but rather an ongoing dynamic system. Having completed the HACCP study and ensured that the CCP's are being monitored, many people breathe a sigh of relief and congratulate themselves that they are using HACCP to manage food safety. However, this is not the end of the HACCP process, rather only the beginning.

In order for HACCP to be functioning optimally, it needs to be maintained and kept 'alive' through regular review meetings. Dynamism and flexibility must be an integral, clearly stated, facet of any good HACCP plan and a philosophy of continuous improvement of the system should, therefore, be adopted.

It must be clearly stated that HACCP must not be over complicated. During its development the idea is not to create a complicated unmanageable system, but rather a simple and focussed system with clear objectives. Personal experience has shown that companies err by confusing food quality and food safety. Some err by creating unrealistic hazards. Both instances lead to too many critical control points, which in turn leads to confusion and under-control of real food safety issues. A further oftenencountered problem is that of lack of total management commitment. Good intentions will not provide safe food or fish. HACCP is only as good as the commitment of the personnel implementing and managing the programme. This commitment starts with the highest authority in the company and should filter through to all levels (Vail, 1994). Top management should, therefore, define exactly how HACCP will be implemented, maintained and managed and resources such as time, personnel and funding have to be planned. The responsibilities, authorities and hierarchy of employees should also be defined clearly (SABS, 1999). A clear route should be visible for communication 'up and down' and there should be a forum for resolving conflict (Mortimore & Wallace, 1998). A forum for reviewing and continuously improving the system should be established). Without whole hearted and sustained management commitment, HACCP becomes: "just another paper system".

Lack of management commitment leads to lack in committing the appropriate resources (mostly time and money) to implement the system. Unless forced to do so many companies are reluctant to commit themselves to this task. Some companies, who are struggling to make ends meet, simply do not have the funds to bear the cost of implementing HACCP. My opinion is that the problem in fact lies a lot deeper. It is not so much the cost of implementing HACCP which is seemingly too expensive, but rather the cost of upgrading the prerequisite programmes such as GMP. This includes aspects such as upgrading the construction and design of the food or canning plant and its equipment to meet modern hygienic standards – an exercise, which more often than not, does not come cheap. This is particularly true for South African food companies. During the isolation years, many companies neglected to re-invest their profits into upgrading their facilities and equipment to international standards. Now, many of these companies have to absorb the full brunt of these costs in a very short space of time. The history of the South African fishing industry until the mid-1990's, when HACCP became mandatory, is a pristine example. This problem cannot be solved overnight. Hopefully, South African companies and industries, will slowly start learning from each other's mistakes and prevent re-occurrence of this trend.

It must also be remembered that HACCP is implemented by people, if the people are not properly trained, the resulting system will be ineffective and unsound. Many food companies have failed in their HACCP attempts because the system had not been backed up by proper and adequate training. Firstly, top management has to be trained. They can only give their wholehearted commitment if they understand what HACCP actually is, what benefits it can offer the company, what is really involved and what resources will be required. Secondly, the HACCP team should be trained thoroughly in order to conduct the HACCP implementation and maintenance task. Other important disciplines such as buyers (especially raw material buyers), should also be trained in aspects of HACCP. The tendency in South Africa is that buyers have little or no technical knowledge and take incorrect decisions based on price and do not take food safety aspects into account (Venneman, 1998). The major challenge, however, lies in training the main workforce. Ideally all personnel should understand and accept the basic principles of the HACCP system and all personnel should have ownership of the HACCP system. This however, does not happen overnight and only continuous and sustained training will suffice until HACCP becomes a way of life. The South African Department of Education has recently initiated the National Qualifications Framework (NQF) and appointed the South African Qualifications Authority (SAQA), as facilitators, in attempt to remedy the situation. Aspects such as food safety, HACCP and GMP do feature in this process, as they are being included in the compiling unit standards. Furthermore, tax rebate schemes are in place as an incentive to companies to adopt the system (SAQA, 2000). However, the SAQA programme is still very much in its infancy and much more trial and error work has to be done before benefits become visually detectable.

A further realistic problem is that a company cannot properly perform HACCP, unless the food chain prior to and after practices HACCP. All segments of the food industry must be involved, from farm to fork (Henney, 2000). Being first to implement HACCP in South Africa, this problem was very soon experienced by the fish processing industry. For example, a company might process fish fillets in crumbs. A critical point might be metal fragments in the crumbs or harmful chemical compounds in the plastic wrapping. Neither the crumb manufacturing company nor the plastic packaging company knows anything about HACCP and cannot guarantee that their products are free of hazards. The HACCP system is, therefore, technically flawed. The problem originates in the fact that since its development, HACCP has always been aimed at food processors. Very little work has been done locally on applying HACCP to non-food production processes such as: farming; transport; retail; and restaurant operations. The regulatory bodies are implementing steps to legislate HACCP throughout the South African food industry. However, lacking in the process is the back-up guidance which should be provided to each sector of the industry, as well as the resources to police whether it has been done properly.

The fundamental problem however, lies in the fact that HACCP is driven by the wrong forces. In the United States, HACCP is driven by the government agencies, in the United Kingdom it is driven by retail groups. In South Africa, the tendency seems to be that the manufacturing industry is driving HACCP. In order for HACCP to truly succeed, the customer should be the driving force. In other words, if the customer is presented with the choice of two products, he or she should rather choose the product manufactured under HACCP controls, than the one which was not. Much more time and effort, however, needs to be spent before this can happen.

Nevertheless, the South African food manufacturing industry can start the process by implementing HACCP correctly. The fishing industry has the opportunity to lead the way in this regard, because they have had the most exposure to HACCP. Other sectors of the food industry should learn from their mistakes and knowledge gained.

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