'From boat to bowl'
An exploratory study of the implementation of the Hazard Analysis Critical Control Point (HACCP) system in tuna processing in the Solomon Islands

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ABSTRACT

Fish and fish products are among the most internationally traded food commodities of which approximately fifty percent originate in developing countries. This raises concerns about seafood safety and quality for the food industry. The Solomon Islands currently export tuna loins to the European Union (EU), which requires accreditation. This lucrative market requires the Solomon Islands to meet stringent standards stipulated by the EU for fishery products.

The aim of the study was to explore and evaluate factors that influence the implementation of the Hazard Analysis Critical Control Point (HACCP) food safety system at National Fisheries Developments Company Ltd (NFD Ltd) and Soltai Fishing & Processing Company Ltd (Soltai Ltd) in the Solomon Islands, and its effectiveness at meeting stringent EU requirements. A mixed methods research and design was adopted in the study, which involved non-experimental research, survey research and qualitative research (one on one *(talanoa)* interviews).

The study revealed that NFD Ltd and Soltai Ltd are in general terms in compliance with the EU directives (EC 852/2004, EC 853/2004 and EC 854/2004) and the Solomon Islands Pure Food (*fishery products*) Regulation 2005. Furthermore, while NFD Ltd and Soltai Ltd do have a well documented HACCP system in place, the study showed that the majority of workers do not fully understand the HACCP system. The review of Good Manufacturing Practices (GMP) on board the fishing vessels revealed that the Chief Engineers, as far as histamine control and monitoring is concerned, are complying with EU Regulation EC 853/2004 and the Solomon Islands Pure Food *(fishery products)* Regulation 2005.The tests carried out to assess microbiological parameters revealed that, a large number of microorganisms were present at all four sites in the processing factory as indicated by Total Plate Counts, a good indicator of product/surface contamination from environmental sources. Furthermore, survey research revealed that a high proportion (43%) of participants indicated they only adhere to the HACCP system "sometimes" and for some "never" in the factory - which poses significant food safety risk. The qualitative *(talanoa)* interviews showed that culture and low literacy level were major factors that impede the effective implementation of the HACCP system in the processing factory. The study further indicated that, to control food safety hazards (physical, chemical, and biological), the tuna industry needs a collaborative approach among those involved throughout the food processing chain, from the fishing vessels during harvesting, through to the processing factory and product shipment.

Training programmes, including pre-requisite programmes, designed to increase staff awareness of HACCP principles should be comprehensive and ongoing, to ensure sustained implementation of HACCP principles in the workplace. These should be an integral component of the companies' HACCP food safety policies and systems.

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I dedicate this thesis to my late dad, Ernest Hagore who had been inspirational in encouraging me to look to greater heights in search of knowledge and excellence. To those whom I have omitted to mention and acknowledge, nigua na dotho hutu puala itamiu igamu gougovu (Thank you very much).

SOLEANA (PEACE)

Ernest Kolly

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LIST OF ABBREVIATIONS

APC – Aerobic Plate Counts

BRC – British Retail Consortium

CA - Competent Authority

CARs - Corrective Action Requests

CCP – Critical Control Points

CCM – Couple Control Monitoring

CFU – Colony Forming Unit

EMS – Environmental Management System

EC – Enterococci

FAD - Fish Aggregating Device

FC – Faecal Coliform

GMP – Good Manufacturing Practices/Procedures

GOP – Good Operating Practices/Procedures

GDP – Gross Domestic Product

HACCP – Hazard Analysis Critical Control Points

HAZOP – Hazard and Operability Hazard Analysis

HFP – Histamine Fish Poisoning

IFNHH – Institute of Food, Nutrition and Human Health

ISO – International Standardization Organization

ICMSF – International Commission on Microbiological Specifications for Foods

m – Acceptable microbiological level in a sample unit

M – The level which, when exceeded in one or more samples, would cause the lot to be rejected

NFD Ltd – National Fisheries Developments Company Limited

NPHL – National Public Health Laboratory

QCO – Quality Control Officer

QA – Quality Assurance

QC- Quality Control

QRA – Quantitative Risk Assessment

RSW- Refrigerated Seawater

SPC – Standard Plate Counts

SSOP – Sanitation Standard Operation Practices/Procedures

SOP – Standard Operating Practices/Procedures

SOLTAI Ltd – Soltai Fishing & Processing Company Limited

SFIB – Sardine Fish Infusion Broth

TC – Total Coliform

TPC – Total Plate Counts

TVC – Total Viable Count

TQM – Total Quality Management

USFDA – United States Food and Drug Administration

CHAPTER 1 – INTRODUCTION

Food safety and food quality are increasingly important public health issues in the 21st century (Huang, Hsieh, Lin, Lin, Hung, & Hwang, 2006) and a major concern facing the food industry today (Huss, Ababouch, & Gram, 2004). This is because people are becoming more aware of the risks that foods can pose to their health and well-being. A number of surveys have shown that consumer awareness about the safety and quality of their food is increasing (Huss, et al., 2004; Raspor, 2008; Venugopal, 2006a). There has been extensive media coverage of food safety issues such as the *Salmonella* outbreak in the US due to contaminated eggs (Jalonick, 2010), bovine spongiform encephalopathy (BSE) crisis in Europe (Cadwgan, et al., 2002), genetically modified foods (Dona & Arvanitoyannis, 2009; Grunert, et al., 2001), use of growth hormones in animal and aquaculture farming (Smith & Gangolli, 2002), existence of pesticide and dioxin residues in food (Angelika & Marek, 2008; Michele, 2007), recall of Peanut Corporation of America (PCA) products at Westco/Westcott due to confirmed cases of *Salmonella typhimurium* (USFDA, 2009), and "transfer between micro-organisms of resistance to commonly used antibiotics" (Huss, et al., 2004, p. 1). All these examples highlight the increased consumer awareness of the quality of food they consume (Huss, et al., 2004).

Standardization of food safety regulations enhances international trade (Hathaway, 1995). On the other hand, the increase of international trade of food products also brings about food safety issues which are of concern to human well being (FSANZ, 2005). In today's modern society where the raw material is sourced on a global scale, food manufacturing is becoming a complex business (Huss, et al., 2004). Industrialisation has seen the development of new technologies producing a vast array of new food products. It is imperative that research evaluates the new techniques and considers food safety and quality issues throughout the food processing chain, from production of raw materials to sale of the final product (Huss, et al., 2004).

Fish and fish products are at the forefront of food safety and quality improvement because they are among the most internationally traded food commodities. In 2004, worldwide trade in fish and fish products amounted to US$71.5 billion, a 51% increase from 1994 (FAO, 2006) of which approximately 50 percent originated in developing countries (Huss, et al., 2004). Developed countries accounted for more than 70% of total global fish imports with the EU accounting for 39.1%, Japan 19.3% and the US 15.9% (Konandreas, 2006). Furthermore, Langley, et al. (2009), noted that the tuna fishery of the Western and Central Pacific is one of the world's largest fisheries. Annual catches exceed 2 million metric tonnes with an estimated landed value of US$3 billion recorded in 2005 (Langley, et al., 2009).

1.1 Background information of the tuna industry in the Solomon Islands

The Solomon Islands, located in the Western Pacific, has abundant marine resources with its tuna fisheries potentially contributing to the prosperous development of the country. About US$3 billion worth of tuna catch comes from the Western and Central Pacific region, which amounts to more than half of the world's catch (Tolley, 2009) .

The tuna industry in the Solomon Islands can be traced back to 1972 when a joint venture between the Japanese company Taiyo Gyogyo and the Government of the Solomon Islands was established (C. Moore, 2008). The first cannery operated at Tulagi, the old capital of the Solomon Islands until the 1980s when the cannery was shifted to Noro, in the Western Province. The tuna industry underwent several changes of ownership until in the 1980s a new joint venture company between Maruha Corporation (formerly Taiyo Gyogyo) of Japan (51 percent shares) and the Solomon Islands Government (49 percent of shares), was established (C. Moore, 2008).

Photo 1: Soltai Ltd cannery, Noro, Western Province. Loin cleaning in the processing lines

Source: (Philipson, 2008).

Social unrest in the country from 1998-2003 brought further changes to the tuna industry in the Solomon Islands. The former joint venture partner Maruha Corporation Limited of Japan decided to withdraw its shares in 2000, and this brought an end to operations at the once renowned jointly owned tuna company in the southwest Pacific. It was not until late 2003, when the Australian led Regional Assistance Mission to the Solomon Islands (RAMSI) restored law and order in the country, that the Sogavare led Government began to revitalise the company. By then, the Solomon Islands' National Government had resumed full ownership, with 49 percent of shares owned by the Western Provincial Government, an arrangement negotiated in 2001 (Moore, 2008). Early in February 2009, a management deal was negotiated between the Tri-Marine International Company Limited (Tri-Marine), a Singapore based American fishing company which operates in partnership with Soltai Ltd, and the Board of Soltai Ltd for Tri-Marine personnel to take over the key management positions of Soltai Ltd. In 2010, the Solomon Islands Government decided to fully privatise Soltai Ltd which is now owned by Tri-Marine (51 percent), the National Provident Fund (NPF) (29 percent), and the National Government, and Western Province who each own 10 percent (Mamu, 2010a).

The National Fisheries Development Company Limited (NFD Ltd), a subsidiary of Tri-Marine, is now the major supplier of raw material (tuna) to Soltai Ltd, allowing Soltai Ltd to concentrate on the processing and production of tuna loins and canned product to meet local, regional and international markets.

In 1999, the Solomon Islands had the largest domestic based tuna industry of all the Pacific Island countries in terms of volume and value (Barclay, 2007). Likewise during the period of 2000-2004, the Solomon Islands recorded a total tuna catch of 222 308 MT, from both domestic and foreign fleets (Barclay, 2007). Due to closure of the processing factory (Solomon Taiyo Ltd), all frozen tuna were exported from Noro. However, there is inconsistency in the figures, as data provided by the Government Statistics Section, Fisheries Department, and Central Bank of Solomon Islands (CBSI), which monitor all export products of the country and those of the fishing companies do not match (Barclay, 2007). The Solomon Islands Government is planning to further invest in the tuna industry, and proposes to establish three new tuna processing factories in the country to promote the down processing of the raw material rather than exporting frozen tuna (Mamu, 2009). A value added product will therefore maximize benefit to the country.

A recent study conducted by the Asian Development Bank showed that the contribution of the fishing sector to GDP in the Solomon Islands was about 12.8% in 1999. It has been estimated that the annual value of the production from fisheries in the Solomon Islands was about US$80 million in the late 1990s. This was comprised of subsistence fishing (US$8 million), coastal commercial fishing (US$2million), locally based offshore fishing (US$69 million), and foreign based offshore fishing (US$1million) (Porto & Buckley, 2006).

There are many estimates of the value of fishery exports from the Solomon Islands. According to the Central Bank of the Solomon Islands, in 1997 fishery products were worth US$35.5million, which is about 20% of the value of all the exports from the country. More than 90% of the marine product exports have usually comprised tuna and tuna related products, primarily in frozen or canned form (Porto & Buckley, 2006).

Table 1: Summary value of Soltai Ltd Tuna products exports, 2005-2009 (Solomon Islands currency (SBD millions). Source: (MFMR, 2010).

Year	Unit	Frozen fish	Canned fish	Smoked fish	Fishmeal	Cooked tuna loins	Totals
2005	SBD	78,052,747	62,068,551	13,284,995	212,563	30,878,899	184,497,755
2006	SBD	100,508,985	4,751,830	18,202,433	332,625	41,730,700	165,526,573
2007	SBD	107,481,223	13,764,508	3,237,525	528,335	72,031,913	197,043,504
2008	SBD	201,866,170	16,549,246		1,785,938	73,460,076	293,661,430
2009	SBD	No export	17,965,638		590,090	147,635,135	166,190,863

1.2 Overview of food safety in the Solomon Islands

The Food Safety Authority, known as the 'Competent Authority' (CA) of the Solomon Islands falls under the auspices of the Ministry of Health and Medical Services Environmental Health Division (refer to figure 1). The Inspection and Certification Unit (ICU) of the Environmental Health Division is the authorising and certifying authority which oversees the export of tuna (tuna loins and canned tuna) products to the European Union. There are also other line ministries which are involved in administering food Safety such as the Ministry of Agriculture through the Agriculture Quarantine Department who oversee all animal products (import and export) of the country.

The Customs and Excise Department, under the Ministry of Finance, is working alongside the Agriculture Quarantine and Environmental Health Division - Food Safety Unit in monitoring products exported from and imported into the country. The Consumer Affairs Department of the Ministry of Commerce and Trade oversees the consumer rights/issues of food products that are deemed to be unsafe for human consumption and works alongside the Health, Agriculture Quarantine, and Customs and Excise in monitoring food safety issues. The Ministry of Fisheries and Marine Resources is responsible for ensuring the sustainable development and management of the Solomon Island's living marine resources (Porto & Buckley, 2006). Overall the food safety function falls under the Ministry of Health being the 'Competent Authority', the actual implementation and monitoring is a collaborative effort within the government ministries concerned and stakeholders such as the food processors, distributors, wholesalers and retailers (MHMS, 2009).

In terms of the regulatory framework, *the Pure Food Act 1996* is the Principal Act that governs and regulates food safety matters in the Solomon Islands ("Pure Food Act," 1996). Based on the Principal Act, the *Pure Food (fishery products) Regulation 2005* is a specific regulation that regulates and controls the processing of fishery products ("Pure Food (*fishery products*) Regulation," 2005), and the draft *Food Hygiene Regulation 2008* is the specific regulation that regulates all other food processing establishments including restaurants and hotels ("Food Hygiene Regulations (*draft)*," 2008). The emphasis is on the fishery products (tuna) being one of the major export commodities.

In order to capture and maintain this lucrative market, the Solomon Islands has to meet the stringent standards stipulated by the EU Commission for Fishery Products Regulations EC 852/2004, EC 853/2004 and EC 854/2004 (European Parliament, 2004a, 2004b, 2004c). The Solomon Islands being categorized under developing nations has just been accredited to list 1 status of countries authorised to export fishery product into the EU market in October 2009 (Goethem, 2009; Vaarno, 2010).

Overall, the Solomon Islands Government through the Ministry of Health & Medical Services, Ministry of Fisheries and Marine Resources and Ministry of Agriculture and Livestock has developed a National Food Security, Food Safety and Nutrition Policy 2010-2015, as a framework to improving food security, safety and nutrition in the Solomon Islands (MHMS, 2009).

The Animal and Livestock Act 1986 under the Ministry of Agriculture regulates animal products imported into and exported out of the country, likewise the Customs and Excise Act 2002 regulates and monitors products imported and exported out of the country to ensure that specific regulations concerned with food safety are complied with. The Custom and Excise Act is concerned with the revenue that the government will derive from imported and exported products and as such plays an important role in ensuring that whatever is imported and exported does conform to the specific regulations for food safety. The Consumer Protection Act 1995 deals mainly with the protection of consumers' wellbeing with reference to food products imported, and works closely with other government ministries in ensuring that food products imported are safe for public consumption. The Acts and Regulations may vary in context, depending on the functions of the department, but have one thing in common and that is to ensure that food products are safe for human consumption. Whatever is exported and imported into the country must conform to the local regulations and international requirements as far as food safety is concerned.

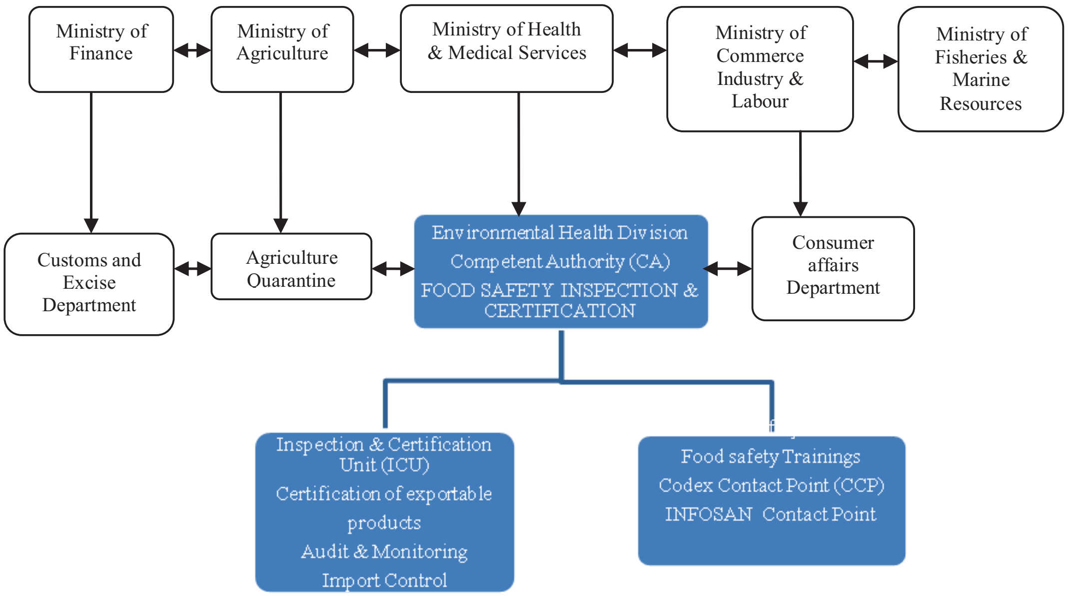


Figure 1: Food Safety Administration and Control Organisational Structure in the Solomon Islands. Source: (Based on my experience as a former EHO in the Solomon Islands).

Figure 1 illustrates the organisational structure of the administration of food safety in the Solomon Islands. This illustrates that the Food Safety Authority in the Solomon Islands falls under the auspices of the Ministry of Health & Medical Services, but its implementation is a collaborative between various government ministries.

1.3 Geographical and demographical features of the Solomon Islands

The Solomon Islands is situated in the southwest Pacific, east of Papua New Guinea and northeast of Australia. The Solomon Islands is the second largest country in the Pacific rim in terms of area (27,556 km^2), with the sixth largest Exclusive Economic Zone (EEZ) in the South Pacific with 1.34 million km^2. The main islands vary in length from 140 to 200 km and in width from 30 to 50 km, and in types from high volcanic islands to raised atolls and low lying islands, sand cays and rock outcrops. The country consists of two roughly parallel island chains with six major higher island groups. Guadalcanal is the largest island (5,340 sq km), while the others scale down from that to less than 1 ha (Porto & Buckley, 2006). Honiara, the capital city of the Solomon Islands is located on Guadalcanal. The estimated population of the country is 518,870 from the 2009 Census (SIG, 2010). Its close proximity to the equatorial zone gives it a hot and humid climate. The country is divided into nine provinces with overall more than eighty seven different indigenous languages. English is the stated official language of instruction at school, although the ‘Pijin’ *(lingua franca)* is the commonly used medium of communication.

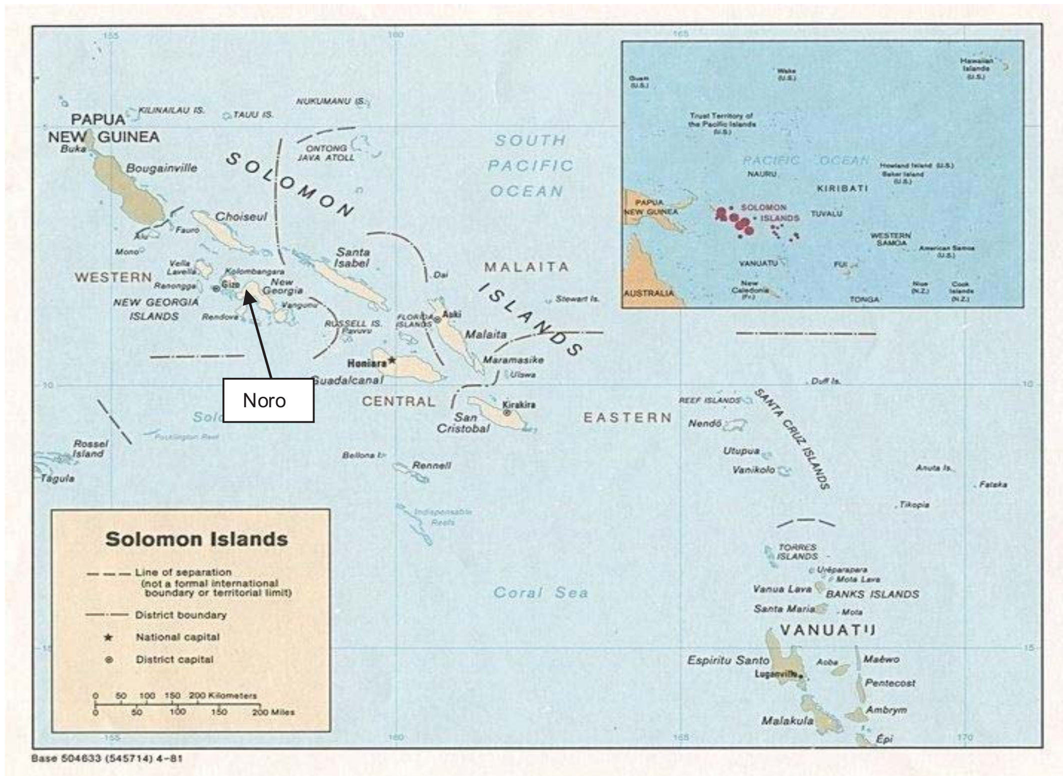


Figure 2: Map of the Solomon Islands and the location of the study site.Source: (retrieved online on the 17th January 2011).

1.3.1 Location of the study site

The NFD Ltd fishing company and Soltai Ltd are both based at Noro in the Western Province (refer to figure 2). The Noro Township is the only industrial centre and the only international seaport outside of Honiara. Noro development is a direct consequence of the presence of the tuna fishing fleet and the tuna processing factory. The industry employs over 800 people of whom 60% are women. Frozen fish, canned tuna, fish meal and frozen tuna loins are all exported from Noro to a number of markets around the world, the EU being the most important. Noro town has an estimated population of 4,000 (T. Mamupio, personal communication, September 27, 2010).

1.4 Problem statement and rationale for the study

1.4.1 Overview

The Solomon Islands is currently exporting tuna loins to the EU, and in 2009 was accredited to List 1 status of countries authorised to export fishery product into the EU market. In order to capture and maintain this lucrative market, the Solomon Islands has to meet the stringent standards stipulated by the EU commission for fishery products (European Parliament, 2004a, 2004b). The Solomon Islands' Government is keen to avoid the difficulties that the tuna industry and the Fijian Government (Baselala, 2009), as well as the governments of other countries such as Pakistan, Malaysia and China encountered when trading with the EU (Campling, 2008).

The Hazard Analysis Critical Control Point (HACCP) food safety management system is internationally accepted as a tool to reduce the prevalence of food borne diseases (Panisello & Quantick, 2001; Ramnauth, Driver, & Vial, 2008; Vela & Fernandez, 2003), however, practical experience and reviews of food safety literature indicate that success in its implementation is dependent on overcoming a complex mix of managerial, organisational and technical hurdles (Bas, Ersun, & Kivanc, 2006; Bas, Yuksel, & Cavusoglu, 2007; Taylor & Taylor, 2004).

In the context of Solomon Islands, the HACCP concept gained importance in late 1990s and early 2000 but was not well understood and therefore not taken on board by all food manufacturers. This was compounded by a delay in the formulation of the food hygiene regulations and food safety policy by the relevant government authorities.

The principles of HACCP became important when Soltai Ltd started exporting tuna loins to the EU in 2004. The recent enactment of the Pure Food (*fishery products)* Regulation 2005 paved the way for HACCP principles to be seriously considered as a tool to enhance food safety in the Solomon Islands. However, no in depth studies have been conducted on HACCP principles and their application in the context of the Solomon Islands, especially in the tuna industry.

There has been a lot of media publicity regarding the safety and quality of the Soltai Ltd canned tuna products in the Solomon Star, (Dorku, 2009a, 2009b; Lakoni, 2009a, 2009b; Mamu, 2010b; Sobaito, 2010; Titili, 2009; Una, 2009; Uteo, 2009) which highlighted the need for proper evaluation of the food safety and quality assurance systems to ensure that the canned tuna products processed at Soltai Ltd do conform to national and international food safety standards. Because of these factors this research is pivotal to the development of the national economy of the Solomon Islands. It is anticipated that the findings will identify potential weaknesses and barriers to the implementation of HACCP in the tuna processing industry, allowing the Solomon Islands to structure a national framework that will enable the Food Safety Authority and the tuna industries to enhance food safety and quality assurance and thus meet national and international standards.

1.5 Aim and objectives

1.5.1 Aim of the study

To explore and evaluate the factors that influences the implementation of the Hazard Analysis Critical Control Point (HACCP) food safety system at NFD Ltd and Soltai Ltd in the Solomon Islands, and its effectiveness at meeting stringent EU requirements.

1.5.2 Specific objectives

1. To review the implementation of good manufacturing practices (GMP) on tuna fishing vessels
2. To investigate histamine content, total plate count (TPC), total coliforms and *Escherichia coli* levels in tuna at the landing site, and during processing within the factory to determine conformity with Solomon Islands Pure Food (*fishery products*) Regulation 2005 and EU regulations and standards EC 852/2004, EC 853/2004 and EC 854/2004.
3. To determine what factors influence the implementation of a documented HACCP food safety system at NFD Ltd and Soltai Ltd.
4. To investigate whether or not the management and workers have a good understanding of the HACCP food safety system currently in place.
5. To explore whether or not the local culture has an influence in the implementation of the HACCP food safety system.

CHAPTER 2 – LITERATURE REVIEW

2.1 Introduction

In the literature review, the historical aspects of HACCP will be outlined, as well as the application of the HACCP principles in practice in the worldwide context.Application of HACCP in the context of the Solomon Islands will be considered along with the application of HACCP in the food industry in general, the fishing industry, small to medium enterprises (SME) and in homes.HACCP principles will be compared with other quality assurance management systems.Finally the slow transition of industry in implementing HACCP principles, and criticism of HACCP principles themselves, will be discussed.

2.1.1 Historical perspective of the Hazard Analysis Critical Control Point (HACCP) system

Hazard Analysis Critical Control Point (HACCP) is a food safety system, established to prevent and control hazards that would have an impact on human health. This gained momentum in the 1980s and re-emerged as the primary focus for quality assurance in food safety in the 1990s (Buchanan, 1990; Panisello & Quantick, 2001). HACCP originally was developed in the United States in the 1960s by the National Aeronautic and Space Administration (NASA), the US Army, Natick Laboratories and the Pillsbury Company to manufacture zero-defect food products for use in the space programme (Adams, 2002; Ali, 2003b). The concept of HACCP has since been widely accepted within the US in various food industries to control and prevent hazards (Adams, 2002).

Although HACCP principles were widely accepted in the US in mid 1970s and late 1980s as a tool to enhance food safety, its acceptance worldwide progressed slowly. This slowness was because of diversified opinion and interpretation of the HACCP concepts by the food industries and government regulatory authorities (Ali, 2003b). One of the significant barriers which slowed the adoption of HACCP principles in the US food industry in the 1980s was the slow integration of the HACCP food safety system into their federal regulatory systems that govern food safety (Ropkins & Beck, 2000a).

It can be noted, that although the HACCP concept originally was developed in the US in the 1970s, it was not until 1988 that the HACCP concept was finally integrated into the Federal and State regulatory agencies (Adams, 1994). This was done after the publication of the 1985 National Academy of Sciences (NAS) report on the *‘evaluation of the role of microbiological criteria for foods and food ingredients’* (Ali, 2003b). Buchanan (1990), states that other limitations to HACCP gaining acceptance in the US are that manufacturers felt that they had less control and responsibility over the products once they are processed and out in the market, and since the focus of HACCP is specifically oriented towards manufactured products, regulatory authorities could not develop generic systems that are applicable to all manufacturing establishments.

The increasing incidences of food borne illnesses (Molins, Motarjemi, & Käferstein, 2001; Raspor, 2008), excess use of pesticides in farms (Angelika & Marek, 2008; Michele, 2007; Smith & Gangolli, 2002), extensive use of artificial chemicals in food manufacturing and increasing illegal use of growth hormones in food manufacturing led to the re-emergence of HACCP food safety system as a tool to enhance food safety and quality assurance in the 1990s (Buchanan, 1990) and the 21stcentury (Tent, 1999).

Kvenberg (1998) stresses the importance of HACCP as a useful tool to achieve food safety and to reduce the likelihood of product liability from injury or illness. Thus HACCP has developed as a means to assure continued consumer confidence in food products**.** The concept has also recently been recognised officially through legislation and regulations developed by governments in many countries as a basis for equivalency in food safety programs to promote international trade (Hathaway, 1995; Lee & Hathaway, 2000; Moy, et al., 1994). The evolution of HACCP can be traced back to a series of formal recognition and adoption activities by the food industry, government and regulatory agencies, and national, international and professional organisations (Ali, 2003b). HACCP is now internationally accepted and recognized as a tool for assuring food safety and quality assurance (Adams, 2002; Kvenberg, 1998; Moy, Käferstein, & Motarjemi, 1994; Ropkins & Beck, 2000a).

2.1.2 HACCP in practice (worldwide context)

A study conducted by Ropkins and Beck (2000) in the EU, North America, Australia, New Zealand and in developing countries, on the implementation of HACCP revealed that its principles have been integrated into the national food safety legislations of many countries, and have been adopted into most food industries. These principles are also likely to form a major component of the standardisation of food quality control and assurance practices for future international trading (Ropkins & Beck, 2000a).The study also highlighted that, regardless of the different approaches taken to implement HACCP, the goal is the same and that is to ensure food safety for the consumers.

In Australia the application of HACCP in the food industry gained momentum in the 1980s (Peters, 1998). The concept was widely accepted and used across broad sectors including the food industries, commercial sectors, Qantas airlines and retail shops. The focus then was on the export of dairy products. Peters recognised that the emphasis of HACCP based quality assurance in the early 1980s was more on the safety aspect rather than the quality. This led to the development of the two voluntary, third party certified HACCP based systems known as the Safe Quality Food (SQF2000®) and Woolworths Vendor Quality Management Systems (WVQMS®) which placed emphasis on both food safety and quality (Peters, 1998). In the US and Canada, the seafood sector were the first to come under voluntary HACCP based inspection programs (Ali, 2003b).

The formation of the New Zealand Food Safety Authority (NZFSA), in July 2007, followed a similar approach to that in Australia, making New Zealand one of the leading countries in the world in terms of safe food trade. Consumer safety and promoting a reputable status as a major supplier of safe food is NZFSA's foremost mission (NZFSA, 2009). New Zealand's food industry is critical to the development of the nation, as the food and beverage sector makes up 20% of the total NZ workforce and is a major contributor to the economy, including primary producers, retailers and processors, restaurants and cafes. Domestic food consumption totals about NZ$15 billion a year and consumption by international tourists adds another NZ$2 billion a year. Eighty percent of the food the country produces is exported, amounting to nearly NZ$20 billion per year (NZFSA, 2009). This highlights the importance of the food industry in the development of the nation, and warrants the establishment of NZFSA as a separate public service department, administering food safety (NZFSA, 2007, 2009). According to Ropkins and Beck (2000a), the New Zealand Ministry of Agriculture's "generic" template for HACCP development is a good example of a user friendly framework to develop HACCP procedures.

2.1.3 HACCP in the context of the Solomon Islands

In the context of the Solomon Islands, the HACCP concept gained momentum in late 1990s and early 2000, but is still not well understood and taken on board by all food manufacturers. This was compounded by a delay in the formulation of the food hygiene regulation and the food safety policy.

The need for HACCP surfaced when Soltai Ltd processing plant started exporting tuna loins to the EU in 2004. The recent enactment of the Pure Food (*fishery products)* Regulation 2005 paved the way for HACCP principles to be seriously considered as a tool to enhance food safety in the Solomon Islands. The implementation of HACCP food safety system in the Solomon Islands is now mandatory. However, the application and acceptance of a HACCP food safety system across all food establishments in the Solomon Islands has not yet happened. Lessons learned from this study will enhance the government's intention to develop a National Policy on

Food Safety, Security and Nutrition (MHMS, 2010), and could form an integral component of the food safety policy.

Food industries are major stakeholders in effecting implementation of the HACCP principles as they are involved in the manufacturing of food products. The HACCP food safety system, like any other quality management tool, will depend on the human factor for its effective implementation (Hielm, Tuominen, Aarnisalo, Raaska & Maijala, 2006; Luning & Marcelis, 2006; Luning & Marcelis, 2007; Luning & Marcelis, 2009). HACCP systems demand that business and staff at all levels are willing to take more responsibility for, and control of, the business's operation, rather than relying on customers, regulators or more senior managers to identify problems and suggest improvements. The success of HACCP implementation in the Solomon Islands' fisheries industry has also been dependent on close cooperation between industry and the Government, and the willingness of the latter to play a proactive role in HACCP implementation.

There are a number of improvements that need to be made on the implementation of the HACCP systems in the Solomon Islands, as the HACCP food safety systems are still concentrated in processing. So far they have not been extended further along the supply chain, particularly in primary production, marine capture and aquaculture. Consumers have still argued for the extension of HACCP principles into such areas as retail sales and consumer handling of fish products (Mae, 2010; Namosuaia, 2010). Implementation of HACCP amongst smaller businesses remains poor. The Solomon Islands' Government needs to keep abreast of changes in HACCP regulations and standards internationally, and there is a need for improved practical guidelines for hazard analysis. Inspectors need to gain more expertise and experience in effective inspection techniques, translating HACCP theory into effective practice. As an example, Inspectors need to use generic HACCP models flexibly, accepting variations which are appropriate to a particular business. There needs to be more research in such areas as the validation of critical limits (Suwanrangsi, 2009). There is also a need to develop adequate and appropriate information dissemination systems on HACCP principles to food industries and the general public in the country.

In order to address food safety risks, it is imperative that a collaborative approach among those involved throughout the food chain, from the primary producer to the consumer, including the Food Safety Authorities, must be taken to prevent further outbreaks of food borne illnesses. In doing so, the Hazard Analysis Critical Control Point (HACCP) food safety system has been recognised internationally as a feasible system that could address food safety and quality assurance issues in the 21st century. In countries like the Solomon Islands where resources (technical expertise, monetary and monitoring facilities) are lacking, strengthening networking nationally, regionally, and internationally and integrating the HACCP food safety system into the food safety legislations and policies would greatly enhance food safety and quality assurance.

2.1.4 Application of the HACCP in the fishing industry

Seafood safety is undergoing a period of unprecedented change, fuelled at the domestic level by increasing consumer concern over food borne hazards, and at the international level by demands for effective food hygiene and food safety control systems across national boundaries. HACCP implementation in the fishery industry worldwide in particular is becoming more widespread in response to these pressures, with importing countries requiring implementation by overseas suppliers. HACCP is recognised internationally as the best tool to control food safety, though there are certain limitations in applying it at the early stage of the production chain. More, recently, risk assessment which involves the process of risk identification, analysis and evaluation (ANZS, 2004) has emerged as an important new technique in assessing microbiological and other hazards. The fishery industry needs to prepare for safety and quality control systems based on risk assessment (Suwanrangsi, 2009).

The use of HACCP systems in the fishery industry is now on a global scale. HACCP principles were embraced by the fish canning industry some 30 years ago ahead of other segments of the food industry, as the sole and most cost effective way to ensure product safety and quality (Ababouch, 2009). Since it first emerged, HACCP has increased in importance, partly through its endorsement by Codex Alimentarius, and partly through its adoption by the EU and USA as a requirement for the import of high risk food products such as fish (Suwanrangsi, 2009).

The applicability of the HACCP food safety system to the seafood sector cannot be overemphasised as illustrated by the botulism outbreak in the US in the 1960s (Adams, 2002), which was associated with improper processing and handling of canned products. Fish is a high protein food and therefore can be easily spoiled by microbial action if not processed properly (Gram & Huss, 1996). Given the complexity of the process that is involved in fish processing, a thorough understanding of the spoilage process and knowledge of the specific spoilage organisms are necessary for the design of an optimal, product specific quality assurance programme in a fish factory (Gram & Huss, 1996). Similarly, Huss (1992) further attests that, the HACCP food safety system which encompasses control of all factors related to contamination, survival and growth of micro-organisms in food in every stage of the food chain, is the best available system to be used in fish factories for improving the microbiological safety of foods.

Ramnauth et al. (2008), in a study to determine food safety management (knowledge, attitude & perception) in the fish industry in Mauritius, revealed that a shortage of financial resources and restricted access to reliable information and expertise, were key barriers to implementation of the food safety management system. The study further highlights that a lack of appreciation by certain participants of the value of a food safety management system in guaranteeing safety, demonstrates the need for a change in attitude. The study goes on to state that, positive perception of the merits of such a study can bring about behavioural change so that appropriate food safety practices are applied (Ramnauth, et al., 2008).

Similarly, the sentiment that HACCP is only applicable to large food industries and would not work in small to medium enterprises (Kirby, 1994) could be a barrier to implementation of HACCP in food industries. This view is also supported by Taylor (2001) and Paniesello and Quantick (2001), who state that, the barriers to implementing the HACCP system in small companies is compounded by insufficient technical resources, a concentration of multiple managerial functions in one person (or only a few individuals), and time and financial incapability to sustain the HACCP system. It is probable that compliance with the HACCP system is a burden on small enterprises (Kirby, 1994; Taylor, 2001) a notion which Maldonado, et al. (2005) rejected, as it is evident from their study of the cost benefit analysis of HACCP implementation in Mexican meat industries, that HACCP is costly but beneficial in the long run. A sentiment Cao (2005) reinforced in her study on the economic analysis of HACCP based risk management programmes in New Zealand Meat industries. Cao went on to emphasise that industry external factors such as gaining market access, meeting legal requirements and customer satisfaction were major motivating factors for the implementation of the HACCP based risk management programme in New Zealand meat industries (Cao, 2005).

A meta-analysis study conducted by Jevsnik et al. (2006), on barriers to implementing HACCP to improve food safety, revealed that approximately 50% of all identified barriers include training, human resources, planning, knowledge, competence documentation, resources and management commitment. Similar studies conducted by Taylor and Kane (2005) affirmed that, success in developing, installing, monitoring and verifying a successful HACCP system depends on overcoming a complex mix of managerial, organisational and technical hurdles. Taylor and Kane went on to state that, even the largest well equipped food companies with significant resources of money, technical expertise and management skills face difficulties, while the small to medium enterprises (SME) often feel that the difficulties of HACCP are potentially insurmountable (Taylor & Kane, 2005).

2.1.5 Application of HACCP in food industries, small to medium enterprises (SME), retail stores and homes

Several studies on the importance of HACCP principles of food safety system in food industries have been conducted worldwide (Hathaway, 1995). The HACCP concept is not always embraced by the food industries in the first instance. A study conducted by Bas, Yuksel and Cavusoglu (2007), focused on determining the difficulties and barriers to implementing HACCP food safety systems in food businesses in Turkey, revealed the following as key barriers to the effective implementation of the HACCP food safety system: lack of pre-requisite programs (92.2%); staff turnover (80.9%); lack of knowledge (83.5%); lack of time (88.7%); complicated terminology (87.0%); and lack of personnel training (91.3%). Sixty three and a half percent reported that they do not really know what HACCP is, and 23.5% stated that it was too complicated. The study further revealed that, only 33% of the managers had attended food safety management training, whilst only 31% of the employees had some basic food hygiene training. The study went on to state that, 91.3% of the managers identified improved customer confidence as a benefit of implementing a food safety management system (Bas, et al., 2007).

Similarly, a Spanish regional survey conducted by Vela and Fernan (2003), to identify barriers to development and implementation of HACCP plans in food companies, revealed that a lack of understanding of HACCP principles, and poor guidelines resulting in inadequate hazard analysis, contributes to poor attitude and behaviour of workers in food companies in Madrid. Azanza and Zamora-Luna (2005) in a study to determine barriers that prevent adherence to HACCP guidelines by team members responsible for implementing standards, showed that the main barrier to adherence was lack of awareness of the principles underlying HACCP.

The HACCP system, to work in practice, depends on the competency of those who develop and implement it, as well as the supporting prerequisite programs (Mortimore, 2001). Mortimore (2001) stressed that HACCP will only work and achieve its goals if there is firm commitment by the management and workers of the food industries. Van Schothorst and Jonegeneel (1994) further argued that food safety is the responsibility of both the food safety authorities and industries. They stated that industries have the responsibility to use the technology at their disposal to ensure food processing is safe, and food safety authorities, as regulatory agencies, are responsible for monitoring compliance with food safety regulations by industries. Similarly, Van Schothorst and Jonegeneel (1992) emphasise that the first step in taking precautionary measures in food safety is to ensure that HACCP systems are included as an integral component of the industries food safety system.

The application of the HACCP food safety system in the domestic sector has been long debated given the complexities that are involved in the environments in our homes/kitchens. HACCP is a systematic food safety management tool and only works through systemic approaches, therefore adopting the systemic strategies employed by commercial sectors in homes is probably not feasible. Application of the HACCP system in the domestic sector is likely to be on an ad hoc basis. However, given the flexibility of the HACCP system (Ropkins & Beck, 2000b), people could modify and tailor the components of the system so that it worked in the domestic sector. Reimers (1994) stresses that, the HACCP system, ever since its origins with the NASA space programme, has seen regulatory and industry groups around the world tailor the system to their specific operating environments.

Ropkins and Beck (2000b), and Reimers (1994) stressed that HACCP is a food safety management system to ensure food safety throughout the whole food chain from the primary producer to the consumer. A study conducted by Reimers (1994) in the US on the application of HACCP principles in retail food stores showed that, given the complexity of how the system in retail shops operates, HACCP can be effectively integrated and incorporated into the businesses' total quality management (TQM) system. What matters is the firm commitment of the management. Therefore it can be assumed that the HACCP food safety management system can potentially be applied across all sectors.

2.1.6 HACCP as compared to other quality management systems

HACCP, as a tool for enhancing food safety and quality assurance, has a close association with other quality assurance management systems, including the ISO 9000 and BS7750 (Adams, 1994); Total Quality Management system (TQM) (Ali, 2003c); the British Retail Consortium (BRC) Global Standards (Van der Spiegel, Luning, Ziggers, & Jongen, 2003); Quantitative Risk Assessment (QRA) (Notermans, 1996; Notermans & Jouve, 1995; Notermans & Mead, 1996; Sperber, 2001); and the Environmental Management Systems (EMS) (Seymour, Ridley, & Noonan, 2007). In addition there are the Quality Assurance (QA) and Quality Control (QC) systems, (Luning & Marcelis, 2007); Couple Control Monitoring Systems (CCM) (Doménech, Escriche, & Martorell, 2008); Good Manufacturing Practices (GMP) (Van der Spiegel, et al., 2003); and the Hazard and Operability Hazard Analysis (HAZOP) systems (Mayes & Kilsby, 1989).

While all the QA management systems mentioned above may have a role to play in food safety, it must be noted that not all QA management systems best address food safety. Van der Spiegel (2003) states that QA systems cover only different aspects of the complete quality system. For example, Good Manufacturing Practice (GMP) according to Van der Spiegel, et al. (2003)

consists of fundamental principles, procedures and means needed to design a suitable environment for the production of food of acceptable quality. Its basic aim is to combine procedures for manufacturing and quality control in such a way that products are manufactured consistently to a quality appropriate for its intended use (Ali, 2003a; Van der Spiegel, et al., 2003).

HACCP on the other hand, focuses on the primary processes and aims to assure the production of safe food products, by identifying and controlling the critical food production steps (Luning, Bango, Kussaga, Rovira, & Marcelis, 2008; Van der Spiegel, et al., 2003). ISO quality systems aim at establishing a coherent strategy whereby a clear chain of command is followed to carry out the food safety activities (Ali, 2003c). ISO 9000: 1994 series were focused more on product conformity to specifications, whilst ISO 9000: 2000 series are focused more on customer satisfaction and prevention of non conformity (Van der Spiegel, et al., 2003).

British Retail Consortium (BRC) global standards for food safety encompasses the GMP, HACCP and ISO, and is aimed at providing quality product assurance and food safety, focusing more on food suppliers and retail branded products (Luning, et al., 2008; Mayes, 1993; Van der Spiegel, et al., 2003). Total Quality Management (TQM), according to Van der Spiegel, et al., (2003), is a management system that covers the complete quality system. In comparison to GMP, HACCP, ISO and BRC, TQM is not a quality assurance system, but rather a concept to improve organisational objectives to achieve both external and internal customer satisfaction of the products to minimise and save costs initially (Ali, 2003c).

Likewise, the Environmental Management Systems (EMS) were designed and are commonly used by agricultural industries to suit their needs and its application is on a voluntary basis (Seymour, et al., 2007). However, there is a strong drive by the industries nowadays to integrate the EMS with other requirements such as the quality assurance systems.Environmental monitoring is designed to provide a microbiological assessment of a plants environmental control program. It is not, in itself a control program, but rather a tool to provide information to improve environmental controls (Clute, 2009a). Information should be used to correct problem areas before they pose a risk to products. Raw wastewater discharge areas are not included in a monitoring program because they are considered to be positive (Clute, 2009b).

Preventive measures such as Good Manufacturing Practices (GMP), supplemented by the HACCP system, have been introduced as a means of ensuring safe production of food. Good Manufacturing Practices (GMP) have been used widely in food industries as the basis for developing and establishing food safety programs within food processing establishments (Ali, 2003a). However, their use does not necessarily provide quantitative information on the risks associated with consumption of a particular food product. To obtain such information, elements of the Quantitative Risk Analysis (QRA) need to be used (Notermans & Mead, 1996).

Quantitative Risk Analysis according to Codex Alimentarius Commission (CAC, 1999, p. 2) is defined as " a risk assessment that provides numerical expressions of risk and indication of the attendant uncertainties".Taking this definition, five successive steps can be recognised; hazard identification, exposure assessment, dose response assessment, risk characterization and risk management (Notermans & Mead, 1996).Quantitative Risk Analysis (QRA) also relates to the end product testing of microbiological conformity to standards. Quantitative Risk Analysis arose to supplement the GMP, HACCP and other quality assurance systems in providing quantitative information to risks associated with food borne illness (Notermans, Gallhoff, Zwietering, & Mead, 1995; Notermans & Jouve, 1995; Notermans & Mead, 1996).

The terms quality assurance and quality control are sometimes misinterpreted although they complement each other. Quality assurance activities focus more on setting requirements for the quality system, which includes planning, monitoring the operation, recommending corrective actions to remedy non-conformity, evaluating its performances, as well as organising necessary changes (Ali, 2003c). Whereas, the quality control system focuses more on basic activities of food quality management, ensuring that product properties, production processes, human factors and process limits conform to standards. It is more an ongoing process of evaluating performance of both technological and human processes and has close linkage to quality assurance (Luning & Marcelis, 2007). Hazard and Operability Hazard Analysis (HAZOP) conversely, is a process originally developed for chemical industries which encompasses an interactive approach toward identification of potential hazards (Mayes & Kilsby, 1989), and could be adapted for use in food industries in the process of hazard analysis.

As a result of comparing and contrasting the different quality assurance systems that are available for food industries, the HACCP food safety system is the only quality assurance system that is systematic and feasible (Van der Spiegel, et al., 2003; Van Schothorst & Jongeneel, 1992). It constitutes a structural, rational, multi-disciplined, datable and cost effective approach of preventive quality assurance (Huss, 1992). HACCP is internationally recognized as the ideal method of assuring safety by controlling food-borne safety hazards. At present, it is the widely acknowledged, cost effective method of controlling hazards in fishery products. Introduction of HACCP based regulations for fish and fish products, particularly in the EU and the US, has triggered the need for the implementation of the HACCP system in most fish exporting countries (Venugopal, 2006b). The HACCP system has been incorporated in the food legislation of many countries therefore, its implementation in food industry is mandatory, whereas the other quality assurance systems can be applied on voluntarily basis in the food industry (Van der Spiegel, et al., 2003). In conclusion, therefore, the HACCP system is potentially the best option to enhance food safety in the 21st century worldwide (Tent, 1999).

2.1.7 Transition to HACCP

The prerequisite programs which deal with the enforcement of Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) constitute essential prerequisites for the transition to the implementation of HACCP methodology (Bonne, Wright, Camberou, & Boccas, 2005). In order to make sure real and effective implementation of the prerequisite programs, the HACCP process has to be thoroughly applied to the tasks in an orderly sequence (systematically), as each task leads on to the next. Inconsistency or side-stepping one or more tasks, or being satisfied with incomplete implementation, will lead to a system (process) failure. HACCP, according to Bonne, et al. (2005), involves two main processes to be carried out, each with definable results. These include the application of the seven HACCP principles, and the implementation of the twelve tasks for analysis, effective control and system review. The two major components of the HACCP food safety system are (a) hazards analysis, which aims to identify the critical control points (CCP) of the process, and (b) control of these points to ensure effective implementation of food safety at each critical control point in the overall food production process (Bonne, et al., 2005).

2.1.8 Different steps in HACCP

The seven principles of a HACCP programme are:

- "Conduct a Hazard Analysis
  Identify potential hazard(s) associated with food production at all stages from growth, processing, manufacture and distribution until the point of consumption. Assess the likelihood of occurrence of the hazards and identify the preventive measures for their control
- Determine the critical control points (CCPs) of these hazards
  Determine the points/procedures/operation steps that can be controlled to eliminate the hazards or minimise its/their likelihood of occurrence-the critical control points (CCP).
- Establish critical limits
  Establish critical limits which must be met to ensure each CCP is under control, and establish operational criteria (limiting values, target levels, tolerances)
- Establish a system to monitor control of the CCPs
  Establish a monitoring system to affirm real and effective control of the CCPs

- Establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control
- Establish procedures for verification that include supplementary tests and procedures to confirm that the HACCP system is working effectively
- Establish documentation concerning all procedures and records appropriate to these principles and their application" (Ali, 2003b, p. 123).

2.1.9 Criticisms of HACCP

Like many other quality management systems, HACCP has its critics which explain why its acceptance in the food industries is progressing slowly. Slow embrace of HACCP principles by the food industries in the US, is probably due to slow integration of HACCP into the federal food safety regulations (Taylor, 2001).Without regulations, not surprisingly, industry is unlikely to comply. Kirby (1994), claims that HACCP is only applicable to large food industries and will not work in small to medium enterprises. This view is supported by Taylor (2001) and Panisello & Quantick (2001) who state that the barriers to implementation of HACCP systems in small companies is compounded by insufficient technical resources, concentration of functions in small enterprises, time, and financial incapability to sustain the HACCP system. It is assumed that compliance with the HACCP system is a burden on small enterprises (Kirby, 1994; Taylor, 2001) a notion which Maldonado, et al. (2005) reject as it is evident from their study of the cost benefit analysis of HACCP implementation in Mexican meat industries that HACCP is costly but beneficial in the long run. Huss (1992) summarizes the various criticisms of the HACCP system as follows;

1. "There continues to be non uniform understanding of HACCP nationally and internationally.
2. There is no universal agreement on what constitutes a hazard (e.g. presence of *Listeria monocytogenes* in raw food).There is a need to establish an international body consisting of non-political but highly respected scientifically members who can advise on safety issues and current scientific thinking on hazards in foods
3. To be effective, HACCP needs to be applied from origin (sea/farm) to consumption. This may not always possible.
4. HACCP deals with uniqueness; regulations deal with the general. This problem may be difficult for regulatory agencies to understand and accept, thereby delaying the application of the system
5. Acceptance of HACCP requires mutual trust.Unless trust exists or can be created between the regulator and the regulated, the system will fail
6. HACCP requires processors to accept greater responsibility. This may cause some resistance from processors who normally rely on government services (inspectors,

laboratories) to guarantee safety and quality. Furthermore it can lead to a perception that HACCP results in reduced inspection and loss of regulatory control even though the intent of HACCP is just the opposite

7. It will take a long time to train inspectors and industry personnel to arrive at one common understanding of HACCP.
8. Application of HACCP will not prevent all problems and experts may disagree on vital issues" (Huss, 1992, pp. 42-43).

2.2 Bacterial contamination

Microbial contamination of food is a major concern for food industries, regulatory agencies and consumers worldwide (Danin-Poleg, et al., 2006; Wu, 2008). Among the micro-organisms found in foods, bacteria constitute the most important groups not only because they are predominantly responsible for food spoilage and transmission of food borne diseases (Sinell, 1995), but also because of their rapid growth rate, ability to utilize food nutrients, and the ability to survive and grow under a wide range of temperatures, aerobiosis and pH (Ray & Bhunia, 2008).

Bacteria of importance to food safety, and for transmission of food borne illness, are numerous. One of the greatest risks to seafood safety is the potential for injured micro-organisms to resuscitate and continue to survive and grow. As Wu (2008) states, injured micro-organisms present a potential threat to food safety since they may repair themselves under suitable conditions and can become functionally normal in a favourable environment.This may lead to further outbreaks of food borne illness, especially if the food does not undergo proper processing and handling.

"Contamination of seafood with bacterial pathogens at source in the sea primarily arises from two different origins. The first with bacteria that occur naturally in the marine environment which, when consumed in seafood in large enough numbers, will cause illness in humans. This primarily relates to the *Vibrios*. Some species of the genus *Aeromonas* are considered by some to possibly cause gastroenteritis in humans and these may also be present naturally in the marine or more especially the estuarine environment" (Lee & Rangdale, 2008, p. 254). Lee and Rangdale went on to state that spores of type F *Clostridium botulinum* are found widely in marine sediments and in the intestinal tract of fish and shellfish and if seafood is stored under conditions principally in the absence of oxygen that allows the spores to germinate and the bacteria to multiply, toxin may be formed in the seafood and then cause botulism when the food is consumed (Lee & Rangdale, 2008).

There are numerous ways whereby the bacteria can contaminate seafood. The most common ones come from polluted waters due to improper disposal of human and animal waste discharged into the ocean. The fish or seafood could also be contaminated when someone touches it with dirty hands or it comes in contact with contaminated contact surfaces. The fish may also be contaminated if the fish is not handled or gutted without care resulted in cross contamination from bacteria that are present in the gut or gills of the fish.

Studies have shown that bacterial contamination can be greater if the fish is stored at high temperatures or has fed just before capture as there would be more bacteria in the gut (Chamberlain & Titili, 2001). In the context of the Pacific Islands, fish can go 'bad' within 12 to 20 hours, depending on the species, method of capture and storage temperature. Some types of fish go 'bad' more quickly than others. For example, white reef fish meat keeps longer in ice than the red tuna meat. This is because tuna have a higher body temperature (which increases during, stressful capture conditions) compared to reef fish, making it easier for bacteria to grow.Their thicker body shape also makes them slower to chill (Chamberlain & Titili, 2001).

2.2.1 Role of bacteria in seafood spoilage

Microorganisms are one of the primary causes of spoilage and off flavours in fish and seafood products (Ouma, 2002). Ouma states that, "the production of consistently high quality seafood product requires the implementation of a thorough cleaning and sanitizing routine that is aimed at reducing the amount of bacteria entering seafood before, during and after process" (Ouma, 2002, p. 7). The continuous evaluation of the processing chain is important to assure the safety and the quality of seafood processed in the factory (Samakupa, 2003).

In general, when a healthy fish is caught, the flesh in its natural state is sterile (Samakupa, 2003), as its immune system prevents bacteria proliferating easily, whereas after death the fish's immune system collapses allowing easy access of micro-organisms into the flesh (Huss, Reilly, & Embarek, 2000).

Most food spoilage is caused by microbial growth and metabolism in food. Food spoilage is a complex process and excessive amounts of food are lost due to microbial spoilage even with modern day preservation techniques. Spoilage is characterised by any change in a food product that renders it unacceptable to the consumer from a sensory point of view (Gram, et al., 2002).

2.2.2 Chemical oxidation and enzymatic spoilage of food

According to Ray and Bhunia (2008) the redox potential of a food is influenced by its chemical composition, specific processing treatment given, and its storage condition in relation to air. Fresh foods of plant and animal origin are in a reduced state because of the presence of reducing substances such as ascorbic acid, reducing sugars and the –SH group of proteins (Ray & Bhunia, 2008). Ray and Bhunia (2008), also state that following stoppage of respiration of the cells in a food, oxygen diffuses inside and changes the redox potential. Processes such as heating can increase or decrease reducing compounds and alters the redox potential. Food stored in air will have higher redox potential than when it is stored under vacuum or in modified gas, therefore, there is high tendency for food spoilage when stored in air compared to the food stored under vacuum or in modified gas.

Enzymes are large protein molecules that act as biological catalysts, accelerating chemical reactions without being consumed to any appreciable extent themselves.The activity of enzymes is specific for a certain set of chemical substrates and it is dependent on both pH and temperature (Periago & Moezelaar, 2001). The living tissues of plants and animals maintain a balance of enzymatic activity. This balance is disrupted upon harvest or slaughter. In some cases, enzymes that play a useful role in living tissues may catalyse spoilage reactions following harvest or slaughter. For example, the enzyme pepsin is found in the stomach of all animals and is involved in the breakdown of proteins during the normal digestion process. However, soon after the death of an animal, pepsin begins to break down the proteins of stomach wall, or may leak out of the stomach, digesting surrounding tissues, such as muscle tissue, making them more susceptible to microbial contamination (Braun, Fehlhaber, Klug, & Kopp, 1999).

A common example of enzymatic spoilage of seafood is the production of histamine in certain tuna fish species due to enzyme action aided by abuse of time and temperature (Lehane & Olley, 2000). Scombrotoxin fish poisoning incidents have occurred due to high levels of histamine, produced by the action of bacterial decarboxylase enzymes on the amino acid histidine, which is found in the flesh from the family of *Scomberesocidae* and *Scombridae* and in lesser amounts in other pelagic fish species (Bjornsdottir, Bolton, McClellan-Green, Jaykus, & Green, 2009).

2.2.3 Histamine fish poisoning

Histamine fish poisoning (HFP) is a food-borne chemical illness associated with the ingestion of histidine rich scombroid fish such as tuna, bonito and mackerel in which histamine producing bacteria produce large amounts of histamine (Kanki, Yoda, Tsukamoto, & Baba, 2007). Histamine is a biogenic amine produced during microbial decomposition of scombroid fish. Biogenic amines are non volatile amines formed by decarboxylation of amino acids such as histidine (Bulushi, Poole, Deeth, & Dykes, 2009). Bulushi, et al. (2009), state that, although many biogenic amines have been found in fish, only histamine, cadaverine and putrescine have been found to be significant in fish safety and quality determination.

The presence of increased levels of histamine in the tissue of fish such as tuna is considered a good indicator of temperature and time abuse and thus a measure of just how good the good manufacturing practices are in the handling of such fish (Patange, Mukundan, & Kumar, 2005). It is worth noting, however, that several species of non-scombroid fish such as mahi-mahi, marlins, bluefish, herring and sardine have also been implicated in incidents of scombroid poisoning (Hsu, et al., 2009).

Histamine is recognised as the causative agent of scombroid poisoning (Kung, et al., 2009). Scombroid poisoning is a severe illness with a variety of symptoms including rash, urticaria, nausea, vomiting, diarrhoea, flushing and tingling and itching of the skin (Chen, et al., 2008). Less than 2 hours from consumption of fish with significant amounts of histamine, symptoms can be observed (Economou, Brett, Papadopoulou, Frillingos, & Nichols, 2007). Up to 5 mg of histamine per 100 g meat is considered normal and acceptable. A histamine concentration of 20mg/100g is considered to be threshold to clinical poisoning, while levels over 100mg/100 g are related to severe poisoning (Lavon, Lurie, & Bentur, 2008). Histamine is heat stable and is not destroyed by different cooking methods (Economou, et al., 2007; Lavon, et al., 2008). The EU acceptable level for histamine as stipulated in EC 2073/2005 are m = 100 mg/kg (100 ppm) and M = 200 mg/kg (200 ppm) (European Parliament, 2005).

A study conducted by Klausen and Huss (1987), to determine generation times (G) of histamine production by the bacterium *Morganella morganii* under various temperature conditions revealed that, growth was rapid at 15-25°C (G =2.6 hrs at 15°C and G = 1.08 hrs at 25°C). At lower temperatures growth was greatly reduced. Growth and histamine production by *M. morganii* in histidine containing broth (HDB) and in mackerel (packed in air permeable plastic bags) was studied. The study further revealed that large amounts of histamine are formed at low temperatures (0-5°C) where no growth takes place, subsequent to storage at higher temperatures (10-25°C).

A study conducted by Ababouch et al. (1991), to identify the isolation of bacteria from sardine (*Sardina pilchardus*) stored in ice at ambient temperature (25°C) revealed that, amongst the 568 bacterial isolates analysed, only 55 were histamine producing bacteria (HPB). Microbiological tests identified 51 of the 55 isolates as *Enterobacteriaceae,* of which 35 were *Proteus sp*. Prolific HPB were *Morganella morganii* (seven isolates) *Proteus vulgaris* (two isolates), *P. mirabilis* (one isolate), *Providencia stuartii* (two isolates), unidentified species of *Proteus* (20 isolates). The *Proteus* species were very active histamine producing bacteria as they produced over 16 μmol histamine ml^{-1} on sardine fish infusion broth (SFIB) in 24h. The in vivo study of histamine production by three species of Proteus showed that the strains were more active at pH

5 than at pH 7 and at 25°C than at 4°C or 35°C. The addition of 8% NaCl (saline solution) to the SFIB and refrigeration at 4°C effectively reduced the histidine decarboxylase activity of the strains. The study concluded that optimal conditions for histamine production by two of the three strains in SFIB were at pH 5, 4% NaCl at 25°C and pH 5, 0% NaCl at 25°C for the third strain (Ababouch, et al., 1991).

Similar studies were conducted by Allen, et al. (2005) to detect and identify histamine producing bacteria associated with standard industry practices during harvesting, receiving and processing of mahi-mahi and yellow fin tuna in North Carolina. Twenty nine composite samples were obtained from 18 mahi-mahi and 11 yellow fins.The study revealed that no sample analysed exceeded 2 ppm histamine, the lower detection limit using the ELISA – based Veratox histamine assay test. Of the 43 isolates tested, 5 were confirmed as histamine producers and all 5 produced low levels (< 250 ppm in 48 h at > 15°C). Three gram negative and two gram positive isolates were identified as *Enterobacter cloacae* and *Staphylococcus kloosii*. The study further revealed that Gram negative bacteria might not be solely responsible for histamine production in at risk fish.The confirmation of histamine producing bacteria demonstrates the potential risk for histamine production.However, no detectable levels were found in the composite fish muscle samples analysed even though 60% of the yellow fin tuna harvested did not meet USFDA regulatory hazard analysis critical point guidelines for temperature reduction (Allen, et al., 2005).

As far as exporting tuna loins to the EU is concerned, all fishing vessels used for catching and storage of fishery products must conform to the requirements stipulated under Regulation EC 853/2004 section Vlll: Fishery Products, chapter 1: requirements for vessels, part a-c (European Parliament, 2004a).

HACCP is industry oriented, and one reason for implementing HACCP is to ensure that hazards (physical, biological and chemical) are minimised and controlled from source to product shipment (Ouma, 2002). To control the formation of histamine and prevent contamination of fishery products at source, the GMP on board the tuna vessels must comply with the requirements stipulated in EU regulations. In the Solomon Islands, fishing vessels supplying frozen tuna to the processing factory (Soltai Ltd) have to be registered, and meet the requirements of EU regulation EC 853/2004 and the Solomon Islands Pure Food (*fishery products)* Regulation 2005 as follows:

European Commission Regulation (EC) 853/2004 clearly stipulates that;

1 "Vessels must be designed and constructed so as not to cause contamination of the products with bilge water, sewage, smoke, fuel, oil, grease or other objectionable substances
2 Surfaces with which fishery products come into contact must be of suitable corrosion-resistant material that is smooth and easy to clean. Surface coatings must be durable and non toxic
3 Equipment and material used for working on fishery products must be made of corrosion-resistant material that is easy to clean and disinfect
4 Vessels water intake for water used with fishery products must be situated in a position that avoids contamination of the water supply" (European Parliament, 2004a).

Time and temperature are the critical determinants to control histamine formation on board the tuna vessels. It is a requirement under the EU EC 853/2004 and the Solomon Islands Pure Food (*fishery Products*) Regulation 2005 that vessels equipped for chilling fishery products in cooled clean seawater must incorporate devices for achieving a uniform temperature throughout the tanks. Such devices must achieve a chilling rate that ensures that the mix of fish and clean seawater reaches not more than 3°C six hours after loading and not more than 0°C after 16 hours (European Parliament, 2004a). The reason for ensuring that the temperature should be maintained at 0°C within 16 hours is to quickly stabilise the fish temperature with the chilled water temperature and ensure that histamine is under control within a short time span. Dead fish held in the net more than 6 hours are considered suspect, (Burns, 1985), because prolonging the time and temperature of the tuna fish in the nets would enhance histamine formation.

According to US Food and Drug Administration requirements (FDA), fish should be placed in ice or in refrigerated seawater (RSW) or in brine at 4.4°C (or less) within 12 hours of death, or placed in RSW or brine at 10°C or less within 9 hours of death. Large tuna (> 20kg) that are not eviscerated before on board chilling should be chilled to an internal temperature of 10°C or less within 6 hours (FDA, 2001).

In order to maintain good quality tuna fish and to avoid decomposition, the core temperature of the fish should be at 0°C within 16 hours. Thereafter, RSW is replaced by brine to further enhance storage of the frozen tuna. It is a requirement under the EU regulations that freezer vessels must have the capacity to lower the temperature rapidly to achieve a core temperature of the frozen tuna not greater than -18°C (European Parliament, 2004a). However, based on my experience as a former Quality Control Officer of the NFD Ltd fishing company, -18°C can be difficult to achieve on board fishing vessels, as it depends on the type of refrigeration system on board the vessel, the capacity and size of the vessel, and the quantity and size of fish landed per catch. In most cases, the core temperature of the frozen fish was maintained at not more than -9°C as stipulated in the EU EC 853/2004 and the Solomon Islands Pure Food (*fishery products*) Regulation 2005 (European Parliament, 2004a; Pure Food (*fishery products*) Regulation," 2005).

The temperature of RSW (or chilled seawater) and salinity of the brine,are critical to controlling the formation of histamine as well as contamination from microorganisms, and subsequent quality of the tuna. The acceptable salinity of brine ranges from 20-24%, though in most cases, the salinity of 23% is maintained and temperature should not rise above -3.8°C (Burns, 1985). Fresh brine should be stored at a temperature -15°C above its freezing point (fp). Therefore, it is important to have temperature monitoring devices on board tuna fishing vessels to monitor temperature of the brine and fish in the wells. For verification purposes, it is important to keep hard copy records of the histamine monitoring records to be verified by external auditors.

High salinity of the brine will affect the quality of the frozen tuna. For example, it results in excessive salt uptake by the flesh and undesirable changes in colour, texture and flavour due to slow freezing and prolonged storage in brine (Burns, 1985). In order to maintain the quality of the tuna fish, and to ensure that GMP as per the EU regulations are adhered to, brine should be changed after 3 to 4 fishing trips, depending very much on the catch per trip and quality of the brine (NFD, 2008). Fish wells for storage of frozen fish must be free from possible oil/fuel contamination.

2.2.4 Indicator organisms

Microbiological criteria for food safety may use tests for indicator organisms that suggest the possibility of a microbial hazard. *Escherichia coli* in drinking water, for example, indicates possible faecal contamination and therefore the potential presence of other enteric pathogens (T. J. Montville & Mathews, 2008).Estimation of indicator micro-organisms in a product can provide simple, reliable,and rapid information about process failure,post processing contamination, contamination from the environment, and the general level of hygiene under which the food was processed and stored (Pierson, Zink, & Smoor, 2007). A microbial indicator is a micro-organism or group of micro-organisms that is indicative of the possible presence of pathogens, and the detection and enumeration of indicator organisms are widely used to assess the efficacy of sanitation programmes (Lues & Tonder, 2007). Their presence in given numbers indicates inadequate maintenance of food safety principles in the processing chain (G. Moore & Griffith, 2002).

The greatest risk lies in the fact that many food pathogenic bacteria are able to attach to food contact surfaces (such as benches) and remain viable even after cleaning and disinfection (Ravin, et al., 2003). Ravin, et al. (2003) stated that, such adhered bacteria can detach during production and contaminate other fresh food as it passes over the contaminated surfaces. Micro-organisms attached to and growing on a surface are called microbial biofilms (Ravin, et al., 2003). The formation of microbial biofilm on the surface of fish processing equipment increases the threat of a cross contamination of the product (Reynisson, Guobjornsdottir, Marteinsson, & Hreggviosson, 2009). This can have a significant influence on the quality and safety of the final product, especially if specific spoilage organisms or pathogenic bacteria become dominant in the biofilm (Ravin, et al., 2003).

Indeed fish and other free swimming marine animals do not normally carry organisms particularly of mammalian microflora such as *E. coli*, faecal coliforms and enterococci.The presence of human enteric organisms on seafood is a clear evidence of contamination from a terrigenous source (ICMSF, 1986).

"Coliform bacteria are the indicator organisms whose presence in seafood in large quantity indicates the probability of having pathogenic bacteria.Faecal coliforms are considered to be present, especially in the gut and faeces of warm blooded animals.Because the origins of faecal coliforms are more specific than the origins of the total coliforms group, faecal coliforms are considered a more accurate indication of animal or human waste than the total coliforms" (Hossain, Mandal, & Rahman, 2010, p. 127).

There is no universal agreement about which indicator micro-organism(s) is most useful, nor are there federal regulations mandating a single standard for bacterial indicators.Thus, different indicators and different indicator levels identified as standards are used in different countries (Samakupa, 2003).Today the most commonly measured bacterial indicators are total coliforms (TC), faecal coliforms (FC) and enterococci (EC). More recently, *E.coli* (a subset of the FC group) and EC were established as preferred indicators by the International Commission on Microbiological Specifications for Foods (Noble, Moore, Leecaster, McGee, & Weisberg, 2003).

2.2.5 Total coliform as indicator bacteria

"Total coliforms are a group of bacteria that are widespread in nature. All members of the total coliform group can occur in human faeces, but can also be present in animal manure, soil, and submerged wood and in other places outside the human body. Thus, the usefulness of total coliforms as an indicator of faecal contamination depends on the extent to which the bacteria species found are faecal and human origin. For recreational waters, total coliforms are no longer recommended as an indicator. For drinking water, total coliforms are still the standard test because their presence indicates contamination of water supply by an outside source" (USEPA, 2010).

2.2.6 Enteric indicator bacteria (*Escherichia coli and* faecal coliforms)

The presence of *E.coli* and faecal coliforms on fish and fishery products, including food contact surfaces, is a good indicator of contamination from mammalian sources (Huss, et al., 2000). The primary habitat of *E.coli* and many faecal coliforms is the intestinal tract of humans and other warm blooded animals (Bell, 2002). Contamination of a food with *E.coli* implies a risk that other enteric pathogens may also be present (T. J. Montville & Mathews, 2008). Faecal coliforms including *E.coli* are heat sensitive and can easily be destroyed by heat and may die during freezing and storage of frozen foods (T. J. Montville & Mathews, 2008) therefore the presence of *E.coli* in heat processed fish products may indicate process failure or be due to recent cross contamination of the fish products. The source of faecal coliforms after thermal processing could be a result of poor adherence to the GMPs including poor temperature control. Faecal coliforms are a better indicator than *E.coli* on its own, because faecal coliforms are often present in higher numbers than *E.coli* and the levels of coliforms do not increase over time when the product is stored properly (T. J. Montville & Mathews, 2008). However, when applying microbiological criteria, the International Commission on Microbiological Specifications for Foods has regrouped the seafood categories. Some product groups have been combined because the criteria were the same, and the'faecal coliform' indicator organisms changed to *'E.coli'*(ICMSF, 1986). *E.coli* has been accepted as a better indicator of potentially hazardous contamination than 'faecal coliforms' and is now used as the indicator organism in fish and shellfish (ICMSF, 1986). The change conforms to the criteria used for other commodities and makes possible the use of rapid and more objective analytical methods based on cellulosic and polysulfone membranes (Holbrook, Anderson, & Bairdparker, 1980; ICMSF, 1986; Sharpe, Peterkin, & Rayman, 1981).

The value of testing for faecal coliforms has recently come under scrutiny, because other indicator micro-organisms such as Klebsiella, Enterobacter, and Citrobacter are classified as faecal coliforms, but their presence could give false positive indication of faecal contamination as they can also grow in non-faecal niches such as water, food, and waste (T. J. Montville & Mathews, 2008; Pierson, et al., 2007). Faecal indicators are typically chosen because they may be easily detected and thus used as markers of possible pathogenic enteric zoonotic agents present in the processing environment or coming from the animals themselves (Ghafir, China, Dierick, De Zutter, & Daube, 2008). However, as noted above, faecal coliforms may not be a reliable indicator of faecal contamination (Pierson, et al., 2007). Like *E.coli*, faecal coliforms can become established on equipment and utensils in the food processing environment and contaminate processed foods.Because faecal coliforms do not necessarily indicate faecal contamination in processed foods, *E.coli* is the most widely used indicator of faecal contamination (T. J. Montville & Mathews, 2008).

Enterobacteriaceae or *E.coli* are used to assess enteric contamination; pseudomonas is a psychrotrophic bacterium responsible for meat spoilage and is infrequently used as an indicator for bovine, swine and poultry carcasses and is used for the verification of effectiveness of the HACCP plans (Ghafir, et al., 2008). Pathogenic strains of *E.coli* are transferred to seafood through sewage pollution of the coastal environment or by contamination after harvest (FDA, 1997).

2.2.7 The TPC as an indicator of bacterial contamination

The hands of food handlers in food processing plants are a likely source of microbial contamination that can spread food borne diseases due to poor personal hygiene practices and cross contamination (Lues & Tonder, 2007). One way to determine effectiveness of the cleaning and sanitation programme in a fish processing factory is to conduct a Total Plate Count (TPC). Total Plate Counts frequently are used to monitor the hygiene of the entire food production process. Total Plate Counts which are also known as aerobic plate counts (APC), total viable count (TVC), or standard plate counts (SPC) are defined as the number of bacteria (colony forming units (cfu) per gram in a food product obtained under optimal conditions of culturing. Thus the TPC is by no means a measure of the "total" bacteria population, but only a measure of the fraction of the microflora able to produce colonies in the medium used under the conditions of incubation (Huss, 1994).

Loss of quality in fish products may not be limited to one microorganism but rather to a variety of microorganisms due to the unrestricted environment of the food. In those types of products it is often more practical to determine the counts of groups of microorganisms most likely to cause spoilage in that particular food (Pierson, et al., 2007). A TPC is commonly used to determine "total" numbers of microorganisms in a food product. By modifying the environment of incubation or the medium used,TPCs can be used to preferentially screen for groups of microorganisms such as those that are anaerobic, thermoduric, mesophilic, psychrophilic, thermophilic, proteolytic and lypolytic.Total Plate Counts may be a component of microbiological criteria assessing product quality when that criterion is used to:

- "Monitor foods for compliance with standards or guidelines set by various regulatory agencies

- Monitor foods for compliance with purchase specifications
- Monitor adherence to GMPs" (Pierson, et al., 2007, p. 75).

Microbial stress, such as those caused by low pH and refrigeration may affect the efficiency of TPCs in the enumeration of hygiene indicator microorganisms such as total aerobes, coliforms and fungi (Ferrati, Tavolaro, Destro, Landgraf, & Franco, 2005). Indicator microorganisms, such as total mesophilic microbial load, gram negative bacteria, faecal coliforms and *E.coli* are used to monitor the microbial profiles and ensure food safety (Oh, Shin, Rhee, Costello, & Kang, 2004). An estimate of the microbial load per unit of plant is obtained and can be compared with predetermined specifications. An aerobic colony count of 100 cfu/cm^2 is often used as a standard and counts below that level are indicative of clean surfaces (Blackburn, 2003).

CHAPTER 3 - RESEARCH METHODS

3.1 Introduction

This chapter discusses research methodology, outlines ethics, cultural and safety issues, describes the research framework and design adopted, and presents a summary overview of the different phases of the study. Finally the details of each specific research method, including data collection, analysis, discussion and conclusions will be explained in full.

3.1.1 Research methodology

The overall research strategy adopted was a mixed methods approach,namely: non-experimental research involving laboratory tests to determine histamine (chemical) concentrations, *E.coli* counts, and Total Plate Counts, total colifroms (microbiological), also included a descriptive analysis study of GMP on board NFD Ltd fishing vessels, based on the catch records and histamine monitoring records given to Soltai Ltd, and on the auditing reports conducted by the Competent Authority on NFD Ltd fishing vessels. Another component was survey research using a self-administered survey questionnaire to determine factors influencing the implementation of the HACCP food safety system at Soltai Ltd; and finally qualitative research involving one on one *talanoa* interviews, to determine whether or not the local culture influences the implementation of the HACCP food safety system at Soltai Ltd.

3.1.1.1 Definition of mixed methods methodology

Mixed methods research according to Johnson and Onwuegbuzie (2004) is defined as the "class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or languages into a single study" (Johnson & Onwuegbuzie, 2004, p. 17). They also note that mixed methods research methodology is an; "expansive and creative form of research, not a limiting form of research. It is inclusive, pluralistic, and complementary, and suggests that researchers take an eclectic approach to method selection, the thinking about and the conduct of research. What is most fundamental is the research question and research methods should follow research questions in a way that offers the best chance to obtain useful answers. Many research questions and combinations of questions are best and most fully answered through mixed research solutions" (Johnson & Onwuegbuzie, 2004, pp. 17-18).

What is paramount in mixed methods research is the compatible triangulation of data derived from the research question (Moon & Moon, 2004).

3.1.1.2 *Why mixed methods research?*

Since the line of inquiry to derive data for the study involved both quantitative (non-experimental and survey research) and qualitative approaches, (one on one exploratory interviews as well as a section of the survey), the mixed methods research was deemed appropriate. Furthermore, the scope of the study was to gather baseline information on the application of the HACCP system in the tuna industry in a holistic manner, from source to product shipment, and as O'Cathan and Thomas (2006) state, one of the reasons why mixed methods approach is applied in health research is that it can provide a bigger or richer picture of the issue under study.

Moon and Moon (2004), and Johnstone (2004) state that, some of the important aspects of adopting mixed methods research are its compatibility with using data triangulation. Triangulation according to Johnstone (2004) involves "reviewing and analysing evidence from multiple sources such that the study findings are based on the convergence of information" (Johnstone, 2004, p. 264). Other factors of importance for the mixed methods paradigm are its complementary expansion of the data findings. Complementary means that "overlapping and different facets of a phenomenon may emerge whereas expansion means that the mixed methods add scope and breadth to a study"(Johnstone, 2004, p. 264). The above factors all contribute to the credibility of the study. Armour, et al. (2009) define rigor as the "degree to which researchers can hold themselves to standards of inquiry that address challenges to the credibility of the study's findings" (Armour, et al., 2009, p. 102). Johnstone (2004) further argues that "the strength of the triangulation process lies in its capacity to neutralise any bias inherent in particular data sources, investigators and methods" (Johnstone, 2004, p. 264).

By adopting the mixed methods approach, quantitative data was obtained from the chemical (histamine), microbiological (total coliform, total microbial load/TPC & *E.coli*), descriptive analysis of GMP, and survey of HACCP knowledge and implementation. The qualitative data was derived by conducting one on one exploratory (*talanoa*) interviews with the workers. Ultimately, the contrasting quantitative and qualitative approaches adopted, formed the framework of the mixed methods research used. Armour et al. (2009) stated that "methodological stringency and accuracy of the results are related, because solidity in methods provides greater assurance that the findings are valid" (Armour, et al., 2009, p. 102).

3.1.1.3 *Philosophical perspective*

The debate of quantitative versus qualitative research paradigms has been an ongoing discussion among scholars and researchers in the field of academia (Armour, et al., 2009; Bryman, 2006, 2007; Denscombe, 2008; Freshwater, 2007; Giddings, 2006; Johnson & Onwuegbuzie, 2004).

For example, the ongoing ‘purist’ view of the dichotomy between ‘positivist and non-positivists philosophies is prevalent’ (Doyle, Brady, & Byrne, 2009, p. 175). At the heart of the dispute is the claim that human sciences are fundamentally different in nature and purpose from the natural sciences. The positivists hold the view that the purpose of any science (if it is indeed to be called a science) is to offer causal explanations of social, behavioural and physical phenomena. Likewise, defenders of interpretivism (non-positivists) argued that the human sciences aim to understand human action (Schwandt, 2003). Therefore, given the pragmatic philosophical view that mixed methods methodology holds may serve to overcome the ‘false dichotomy’ surrounding the ‘purists’ view of the quantitative and qualitative paradigms. The emergence of the pragmatic mixed methods approach (Johnson & Onwuegbuzie, 2004) resulted from these ongoing discussions and debates among the scholars and researchers.

Mixed methods research according to Denscombe, 2008; Johnson and Onwuegbuzie, 2004; and Johnstone, 2004; is a research paradigm of its own. It has evolved as a separate methodological framework with its own worldview, vocabulary and techniques (Denscombe, 2008). Denscombe (2008), emphasizes the diversity of ways in which social researchers’ adopt mixed methods research. Researchers may use mixed methods to improve the accuracy of their data, or to produce a more complete picture by combining information from complementary kinds of data sources. Some use mixed methods as a means of avoiding biases intrinsic to single method approaches, essentially a way of compensating specific strengths and weaknesses associated with particular methods. Others may use it as a way of developing the analysis, by building on initial findings using contrasting kinds of data and methods. Mixed methods may even be used as an aid to sampling, for example, the use of questionnaires to screen potential participants for inclusion in an interview program (Denscombe, 2008).

In spite of the variety of uses for mixed method research, reported in the literature, it is concluded that mixed methods research is indeed a research paradigm of its own which can be used and adapted for different research contexts. Johnson and Onwuegbuzie (2004), stress that “mixed methods methodology does not aim to solve the metaphysical, epistemological, axiological and methodological differences between the qualitative and quantitative paradigms and neither is mixed methods methodology there to provide the best solutions for the differences’’ (Johnson & Onwuegbuzie, 2004, p. 16). Rather, mixed methods research is viewed as a methodology that could encompass the qualitative and quantitative philosophies in a workable solution.

3.1.1.4 Application of mixed methods research in health research

In the context of health research, the mixed methods research is an alternative approach to be adopted (Doyle, et al., 2009; Johnstone, 2004). Johnstone (2004), in her health services research exploring the process and organisational consequences of new equipment adopting in surgery, among five Australian hospitals, concluded that mixed methods research, though new and less documented, has increasingly gained momentum and recognition, and been accepted and adopted in health services research to investigate organisational phenomena. Likewise, Doyle, et al. (2009) further reinforced the idea that mixed methods research can now be viewed as a third methodological movement that has much to offer in health and social science research.

Doyle, et al. (2009) emphasise that, mixed methods research emerged as a consequence of limitations that resulted from sole use of quantitative and qualitative methodologies. Given the complexities and multifaceted nature of health related problems, the emergence of the pragmatic approach of mixed methods research could best serve the health sector related research, as it allows and guides health researchers to adopt a dynamic approach to tackle different health problems (Doyle, et al., 2009).

The above arguments in support of mixed methods research are congruent with my interest in conducting a baseline study of what factors affect the implementation of the HACCP principles of food safety system in the tuna industry in the Solomon Islands. In order to determine effective application of the HACCP principles in the tuna industry, an holistic approach was adopted, and that was to critique the HACCP system from source to product shipment. Therefore, in order to critically review the implementation of the HACCP food safety system, both inductive and deductive approaches have been adopted. As Lincoln and Guba (1985) once stated, one of the characteristics of a research problem is that it is "a state of affairs that begs for additional understanding" which implies that "the purpose of research inquiry is to resolve the problem in the sense of accumulating sufficient knowledge to lead to understanding or explanation" (Lincoln & Guba, 1985, pp. 226-227).

3.2 Ethical, cultural and safety issues

Since this study involved human participants, the proposed research was subjected to the approval requirements of Massey University Human Ethics Committee, and the Ministry of Health & Medical Services of the Solomon Islands Human Ethics Committee. Prior to commencing the study a formal letter requesting permission to conduct the study was sent to the Solomon Islands Ministry of Education (seeking a research permit) (refer appendix IV), and to Soltai Ltd (refer appendix II). When approval was gained from the Massey University Human Ethics Committee, the following was added to the research proposal:

"This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 10/12. If you have any concerns about the conduct of this research, please contact Dr Karl Pajo, Chair, Massey University Human Ethics Committee: Southern B, telephone 04 801 5799 x 6929, email humanethicsouthb@massey.ac.nz"

A copy of the research proposal was submitted to the Ministry of Education, Ministry of Health and the companies in Solomon Islands for their reference. The study did not commence until approval was granted by all the concerned authorities. Ethical issues as they specifically apply to each phase of the study are incorporated into the method of data collection of each. Likewise, issues of validity and reliability, pertaining to each research method, are included in the sections offering detailed explanation of each phase of the study.

3.3 Research framework and design

3.3.1 Overview

An outline of the study framework and design is depicted in figure 3. The 4 phases of the study were subdivided into 3 major types of research namely, non experimental research, survey research and the qualitative research (refer to figure 3). Because each type of research has its own set of criteria, which ensure validity and reliability, each will be dealt with separately in terms of how the data were collected, analysed, results presented and discussed. Finally, to round off the study, there will be a summary discussion drawing upon the findings and conclusions of each phase, stressing triangulation of data, which is a major strength of the mixed methods approach.

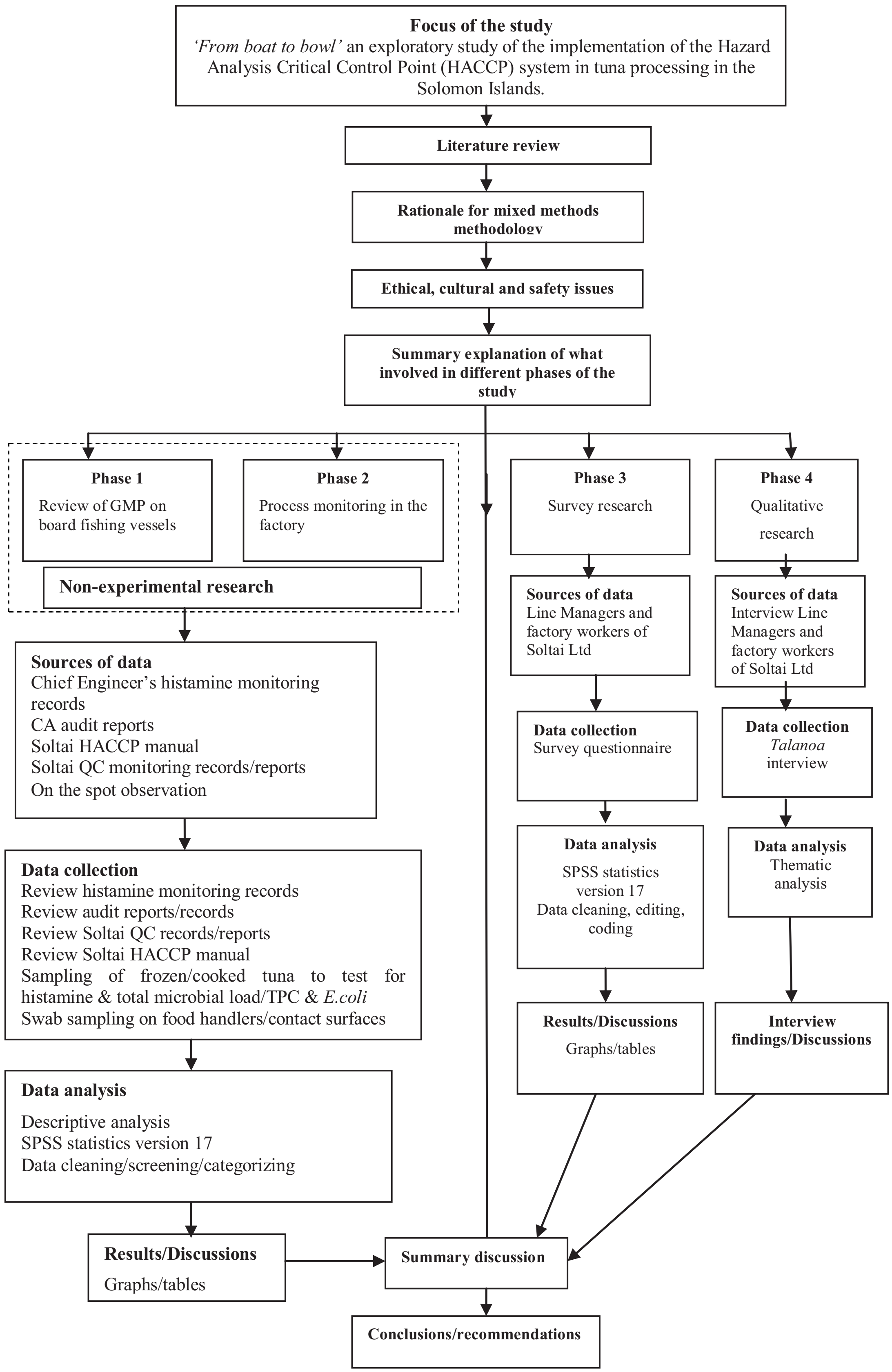


Figure 3: Research framework and design

3.3.2 Summary explanation of what was involved in the different phases of the study

3.3.2.1 Phase One – Review of good manufacturing practices (GMP) on board fishing vessels and histamine monitoring during unloading.

Phase one of the data collection, focused on the fishing vessels which are operated by the NFD Ltd Company and which supply the raw tuna to Soltai Ltd. This phase involved reviewing the aspects relating to the operation and implementation of HACCP in particular the GMP's on board the fishing vessels. However, due to non approval by NFD Ltd management to conduct the study on board the fishing vessels, a descriptive study was conducted instead. This involved reviewing the Chief Engineer's daily catch records report given to the processor (Soltai Ltd) after each fishing trip, and review of the standard sanitation operating procedures (SSOP's)/GMPs on board the fishing vessels using audit records conducted by the Competent Authority on board the fishing vessels. The corrective action requests (CARS) issued by the Competent Authority (CA) to the company fishing vessels, reflect non compliance of the company HACCP manual with the Pure Food (*fishery products*) Regulation 2005.

In addition, fish samples were collected at the landing site to test for histamine, on every unloading trip of the fishing vessels to the factory. The interest in the fishing vessels relates mainly to fish handling and storage on board during harvesting, to control the formation of histamine and other food safety hazards, as well as the maintenance of cleanliness/hygiene on board the fishing vessels. Time and temperature were the key determinants considered on board the fishing vessels.

3.3.2.2 Phase Two – Process monitoring in the factory

Phase two focused on the fish processing factory operated by Soltai Ltd. Microbiological sampling to test for the total microbial load indicated by the total plate count) and *E.coli* was carried out to determine possibility of cross contamination in the processing chain.Total coliforms was also tested by the Millipore test (Millipore, 2006) from thumb swab samples taken from process personnel and food contact surfaces, to determine possible sources of contamination, and to establish possible correlation between histamine build up and microbiological contamination.

3.3.2.3 Phase Three –Quantitative survey

Phase three involved conducting survey research involving a self administered questionnaire to Line Managers and factory workers of Soltai Ltd.

3.3.2.4 Phase Four –Qualitative Interview

Phase four involved one on one exploratory *(talanoa)* interviews with selected Line Managers and factory workers. In addition, an ongoing observation of the behaviour of line workers in the factory was conducted. Data collected from the exploratory interviews, and on the spot observations, were used to determine whether or not the local culture influences the implementation of the HACCP food safety system.

3.3.3 Detailed explanation of the data collection, analysis and result/findings of each research method

3.3.3.1 Phase one and phase two - non experimental research

3.3.3.1.1 Sources of data

Permission was sought from the General Manager of Soltai Ltd to access the company documents especially on HACCP food safety system and quality control monitoring records. A joint agreement (refer to appendix VI) was signed by the General Manager and myself as the researcher, covering conditions to comply with when conducting the research.
Application to conduct the study with NFD Ltd workers was also submitted but permission was not granted by NFD Ltd management to conduct a survey of GMPs on board the fishing vessels. Therefore, the Chief Engineers and Captains of the NFD Ltd fishing vessels were not interviewed, as originally planned, and survey questionnaires were not given out on board the fishing vessels. Instead, a descriptive study reviewing the histamine monitoring records and audit reports conducted by the Competent Authority (Government Auditors) was undertaken to indirectly gather information on HACCP monitoring and compliance on board the fishing vessels. Due to slow turnaround of the vessels unloading fish to the factory, the records of only two fishing vessels were reviewed during the 4 week data collecting period. This was strongly influenced by the duration of fishing time and weather conditions.

The duration of the data collection phase of the whole study was eight weeks in the Solomon Islands. The first week was spent with the National Public Health Laboratory at Honiara to familiarise myself with the ISO bench protocols.The actual data collection time at the processing factory in Noro, including the fishing vessels, was only four weeks. This includes three weeks sampling in the factory as well as distribution of the survey questionnaires and one week to conduct the qualitative interview and follow up of the survey questionnaires. The final three weeks were spent in Honiara.Two weeks collecting contextual data from Government ministries and the final week was spent with the National Public Health Laboratory helping out in preparation of the reagents to be used in the laboratory analysis.

3.3.3.1.2 Company document review & analysis

Permission was sought from Soltai Ltd Quality Control Manager to access the company quality control monitoring records. This included the Chief Engineer's histamine monitoring records. A copy of the histamine monitoring records, compiled by the Chief Engineer on each fishing vessel of the NFD Ltd fleet, which included the time and temperature records, is normally given to the processor (namely Soltai Ltd) on every unloading trip to the factory. This allowed indirect access to information about what took place on board the fishing vessels. In addition reviews of the CA audit reports were conducted at Noro and Honiara offices to determine compliance of NFD Ltd with their HACCP food safety system. To ensure validity and reliability of the data obtained, a systematic review of the Chief Engineer's histamine monitoring records was conducted on every unloading trip to the processing factory.

The systemic review of the daily histamine monitoring records involved assessing the date of catch and source of catch which determines whether the catch was from a school of fish or by a fish aggregating devices (FAD) or what is locally known as payao. The FAD is a man made device used to attract ocean going pelagic fish such as tuna fish and is anchored in the ocean with positions marked by the fishing boats. Fish tend to slowly move around FADs in varying orbits, rather than remaining stationary below the buoys.

In addition fish storage well temperatures were determined; this included the temperature of the refrigerated seawater (RSW) before brailing (sucking up of the fish in the net into the fish wells) and after loading. The time when the sets, sack up, and brailing were started and finished were established. The total tonnage caught/day was also noted as it has close association with histamine formation, i.e., time and temperature being the critical determinants in big sets made..

The time and temperature of the brine was determined as well as when the brine was transferred to the fish wells to replace the RSW. This also involved determining the salinity (%) of the brine. This is important as the salinity (%) of the brine further enhances storage of the fish and thus maintains the quality of the fish (refer to section 2.2.3 for details).The species of tuna caught/day was also determined including establishing the four hourly temperatures recording/monitoring of the fish onboard the fishing vessel prior to commencement of the unloading.

With regard to reviewing the CA's audit reports, the following information was considered:

- The CARs issued to the company.This indicates non compliance and defects noted during the audit.The CARs were issued if the auditors noted during the audit that the company was not complying with their documented HACCP food safety system including the SSOP/GMPs and the Pure Food *(fishery products)* Regulations 2005.

- Number of CARs issued.The number of the CARs issued determines the number (total) of non compliance, the more CARs issued, indicates more defects noted, which indicates non compliance.
- Special attention was given to the details of the CARs issued, as it gives a clue to the nature of the defects noted. This also involves taking note of the auditors' general comments on the audit report.
- Informal interviews were conducted with the CA auditors to determine their view on the implementation of HACCP system by NFD Ltd.

3.3.3.1.3 Histamine sampling

Tuna fish samples, for histamine analysis, taken at the landing site and in the processing factory, were carried out in accordance with the standard operating procedures of the company. To ensure validity and reliability, histamine sampling and analysis were conducted in accordance with the AOAC 937.07a and Solomon Islands Pure Food (*fishery products*) Regulation 2005 ("Pure Food (*fishery products*) Regulation," 2005).

Sampling involved the collection of randomly selected whole fish taken at the time of unloading. The fish were collected randomly from the vessels 10 hatches from top, middle and bottom. Sterile gloves were used when collecting samples to avoid cross contamination from the sampler. The samples were placed in a small esky and brought to the company laboratory. This was to avoid cross contamination from environmental sources and to maintain aseptic technique on sampling. Knives were autoclaved prior to using and in case they came into contact with the food contact surfaces, alcohol was used to sterilise prior to re-using. This is in accordance with the company's standard operation procedures for microbiological sampling.

- Nine fish samples per batch/shipment were collected for histamine analysis representing each hatch/batch during unloading (European Parliament, 2005). Batch as per the Solomon Islands Pure Food (*fishery products*) Regulation is defined as "the quantity of fishery product obtained under practically indentical circumstances, during a period of time from an identifiable processing line and indicated by a specific code" ("Pure Food (*fishery products*) Regulation," 2005, p. 76). Time and temperature of the fish were recorded when samples were taken.
- The fish were cleaned, scaled and eviscerated. Three cross-sectional pieces 2.5cm thick were cut, from the back of the pectoral fin, halfway to vent, and one posterior to the vent.

- Samples were labelled and put in a clean plastic bag and kept in the refrigerator at 2-8°C ready to be analysed ("Pure Food (*fishery products*) Regulation," 2005; Soltai, 2010a). The samples were deboned, and composite samples (9 samples/composite) as per EU Regulation 2073/2005 (European Parliament, 2005) were macerated using a homogenizer until samples were homogenous.
- Samples were now ready for histamine analysis using the Neogen alert test (see 3.3.3.1.5). Tests were carried out in the Soltai Ltd laboratory on site.

3.3.3.1.4 Required equipment for samples

When taking fish samples, aseptic techniques were adopted to ensure that no potential for cross contamination from equipment was incurred especially for microbiological sampling. The following equipment/materials/apparatus as per the CFIA (1998) list were used;

- Fish inspection worksheet, permission to move under detention form
- Notice of detention/notice of release/held tags
- Inspector notebook/pencil/pen
- Hand coverings (plastic gloves, rubber gloves)
- Safety boots and rubber boots, hard hat, coveralls and hairnet
- Clear adhesive tape
- Utility knife
- Marker
- Hand towels
- Plastic bags (various sizes) tags, labels
- Flashlight/batteries
- Thermometer
- Sanitizer and saw
- Sterilizing forceps
- Cooler and ice packs

3.3.3.1.5 Test procedure

Due to malfunction of the company spectrophotometer used to test for histamine levels in fish samples, the Neogen alert test kit was used instead (Neogen, 2008). Unfortunately this test does not yield quantities of histamine, and was not the intended method (test). However, the circumstances encountered during the data collection in the Solomon Islands warranted the use of whatever equipment was at the company's disposal (see section 5.1 for details). It can take months to repair equipment in the Solomon Islands.

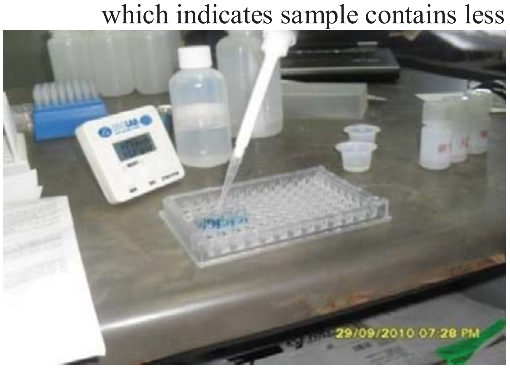
The Neogen alert test for histamine is a competitive direct enzyme- linked immunosorbent assay (CD-ELISA). Histamine was extracted from an homogenized fish sample in a quick water extraction process. The extracts were filtered and then diluted in the buffer solution supplied with the test kit. Free histamine, in the buffered sample and control, were allowed to compete with enzyme–labelled histamine (conjugate) for the antibody binding sites in the test plates. After a wash step, substrate was added, which reacted with the bound enzyme conjugate to produce blue colour. The colour of the sample was visually compared to the colour of the control (refer to photo 3) (Neogen, 2008).

3.3.3.1.6 Interpretation of histamine results

If a sample well is darker blue than the control well, the sample contains less than 10 ppm of histamine. If a sample well shows less blue colour, or redder colour, than the control, the sample contains more than 10 ppm of histamine.

Photo 2: Neogen alert test kits. Different reagents to be used in each step of histamine analysis

Photo 3: Alert test kit sample interpretation. Sample shows a darker blue colour than the control which indicates sample contains less than 10 ppm of histamine.



3.3.3.1.7 Microbiological test methods

For purposes of validity and reliability, microbiological sampling was conducted in accordance with the International Commission on Microbiological Specifications for Foods (ICMSF) (ICMSF, 1986), and with the Canada Food Inspection Agency manual (Fish Products Standards and Methods Manual) for aseptic technique (CFIA, 1998). The ISO 4833:2003 standard for microbiology of food and animal feeding stuffs horizontal method for the enumeration of micro-organisms was used to determine colony count at 30°C (ISO, 2003), and ISO 16649-2:2001 was used for colony counts at 44°C for β-glucuronidase-positive *E.coli* (ISO, 2001). ISO 7218:2007 was referred to for the methods of calculation, and ISO 1669-2:2001 was used to determine *E.coli* colony counts where the plates do not contain any typical blue colonies on tryptone bile x-glucuronide (TBX) media.

3.3.3.1.8 Microbiological sampling

Frozen tuna samples were taken as follows:

- Landing site during unloading (the same fish taken for histamine testing, see 3.3.3.1.3)
- From the thawing area prior to butchering (different frozen fish), and these were tested for total microbial loads (TPC) and *E.coli*.
- 200g of frozen tuna fish samples were taken during the unloading of fish to the factory
- Freshly cooked tuna fish and tuna loins were taken from points along the processing chain, in the factory to test for total microbial load (TPC), *E.coli* and histamine content.
- Approximately 200g of freshly cooked tuna loin samples were collected in each sampling site for microbiological and histamine tests. Likewise, a minimum of 100g of sample was required to carry out each test in the laboratory.
- Samples were taken at four identified sites (thawing area, prior to 1st cleaning, 2nd/3rd cleaning, loin packing/ weighing) in the processing line (refer to figure 4). Choice of these critical points in the food processing chain is consistent with HACCP principles. The sites were identified to determine microbial build up prior to cooking, after cooking, and during production.This is to determine possible relationship between microbiological contamination and food handlers and contamination of food contact surfaces.
- Samples were taken on three consecutive days (Monday, Tuesday & Wednesday) for three weeks to determine consistency of maintaining the SSOP/GMP in the processing chain and give greater insight into the distribution of the microbial contamination at each site along the processing chain.
- Samples were taken using aseptic techniques to ensure that no cross contamination was done.
- All sampling equipment (tongs/knives/forceps) were autoclaved prior to sampling.
- Samples for microbiological tests were kept in sterilised plastic bags and placed in a sampling esky with ice cubes and stored in the freezer at -18°C ready to be air transported to the laboratory at Honiara.
- Samples from the unloaded fish, and processing chain, prepared for microbiology tests, were sent to the National Public Health Laboratory at Honiara on a weekly basis after

the 3rd consecutive day.This is because the Soltai Ltd Quality Control laboratory at Noro is not fully equipped to carry out any food microbiological tests apart from the routine water tests and swab tests on food contact surfaces and food handlers, and histamine. Samples for histamine tests were taken to Soltai Ltd laboratory at site to be analysed.

- Time, temperature of packing, and transportation to the airport were recorded. This is to maintain the cold chain of the samples.
- The calculated results of the total microbial loads (TPC) and β-glucuronidase-positive *E.coli,* expressed as cfu/g,were sent to me in New Zealand via e-mail by the microbiologist in the Honiara Laboratory, once the tests had been carried out.
- It is a requirement of the Soltai Ltd factory that visitors comply with the food safety rules and regulations. Proper clothing, lab coats, hair nets, gumboots were worn while working in the factory and in the laboratory
- All visitors to the factory premises must comply with the company's Occupational Health & Safety rules. Any accidents, or near miss accidents, must be reported to the company management as soon as possible. Overalls, lab coats, gum boots, helmets or caps were worn at all times while engaged in research on the company premises.

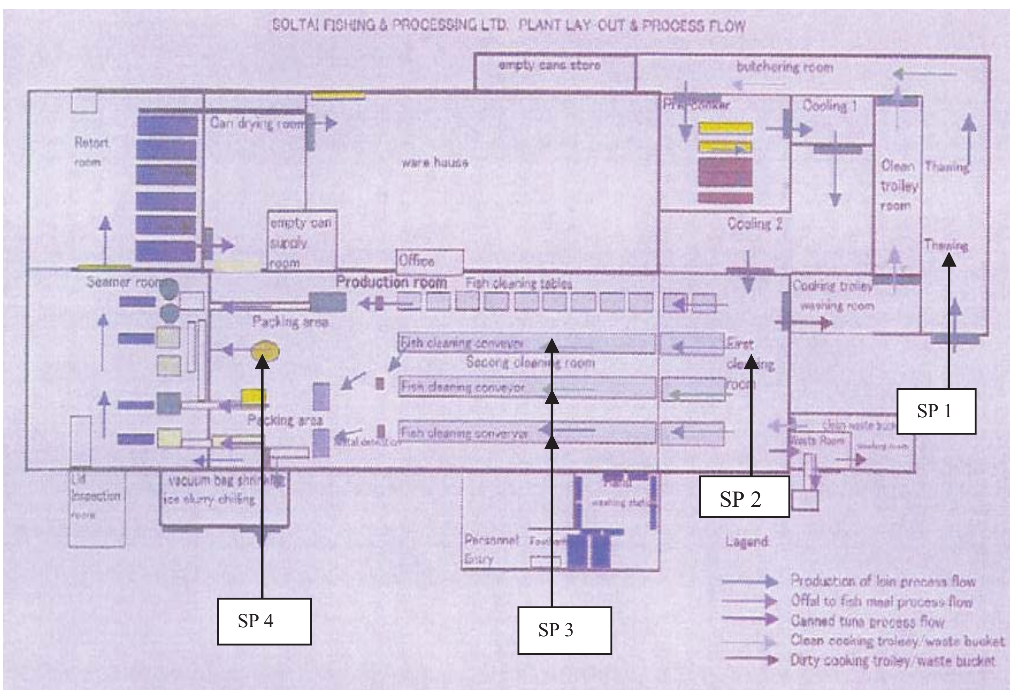


Figure 4: Soltai Ltd plant layout and sampling sites. Source: (Soltai, 2010).

3.3.3.1.9 Sampling on food contact surfaces and food handlers

Swab samples were randomly taken from the thumbs of food handlers on the production line, and from exposed surfaces within the factory. Samples from handlers were coded using alphabetical letters to ensure anonymity. If the participant declined to participate, an alternative participant who volunteered was included in the study.

A total of ten swab samples (3 from food handlers and 7 from food contact surfaces) were taken three times a week. This was to test for total coliforms, a good indicator of contamination of food handler's thumb and food contact surfaces from environmental sources due to poor personal hygiene and sanitation.

- Samples were taken from the thumbs of workers hands prior to, and after they had washed their hands.
- For food contact surfaces, samples were taken from fish trays, loin cleaning knives, the loin moulder, metal detector moulder, metal detector conveyor, stainless steel table and the conveyor lines.
- No template was used in conducting the swab samples on food contact surfaces and food handlers' thumbs, due to very irregular surfaces sampled.
- After the samples were taken, the buffers were placed in an incubator at 35°C for 24 hours.
- Samples were read after 24 hours using a magnifying glass

The Millipore swab test kit was used to test for total coliform presence. "The Millipore swab test kit is a self contained system, incorporating Millipore samplers, and units containing 18mL of sterile phosphate buffer into which are fitted swab assemblies. The system is designed for measuring bacterial levels on flat or irregular surfaces. They can be used in variety of applications in food production, food handling establishments and other facilities to assess the efficiency of sanitation measures used to eradicate microbial contamination. The buffer units contain neutralizing agents to counteract the adverse effect of any residual chlorine or quaternary ammonium compounds that may be present on surfaces after sanitization" (Millipore, 2006, pp. 10-11). Results are expressed in cfu/swab.

3.3.3.1.10 Interpretation of total coliform results

"Coliforms are blue in colour. Non coliforms are green, gray or cream colour"(Millipore, 2006, p. 9).

Photo 4: Swab sampling prior to and after washing of hands. This test is to determine total coliform presence on food handler's thumbs

Photo 5: Swab reading after incubating at 35°C for 22-24 hours. Coliforms are blue in colour. Non coliforms are green, gray or cream colour.

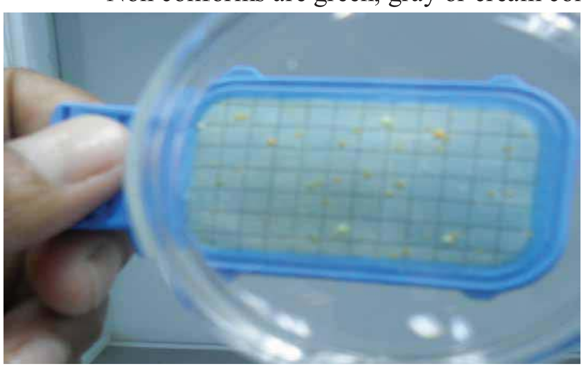


Table 2: Summary of chemical (histamine) and microbiological parameters, total coliform, total microbial load/TPC and *E.coli* samples collected and analysed

Parameters	Method of test	Parameters tested for/unit	No. of samples collected	Where the test was conducted	Equipment used & Incubation time/temperature
Histamine					
Frozen tuna (unloading)	Neogen alert histamine test kit	Histamine (ppm)	18	Soltai Ltd QC laboratory	Homogenizer
Frozen tuna (thawing area)	Neoogen alert histamine test kit	Histamine (ppm)	9	Soltai Ltd QC laboratory	Homogenizer
Freshly cooked tuna loins (Processing factory)	Neogen alert histamine test kit	Histamine (ppm)	27	Soltai Ltd QC laboratory	Homogenizer
Microbiological parameters					
Total Plate Counts (frozen tuna unloading)	ISO 4833:2003	Colony counts (cfu/g)	18	NPHL, Honiara	Stomacher & homogenizer Incubated at 30°C for 72 hrs
Total Plate Counts (frozen tuna thawing area)	ISO 4833:2003	Colony counts (cfu/g)	9	NPHL, Honiara	Stomacher Incubated at 30°C for 72 hrs
Total Plate Counts (freshly cooked tuna loins)	ISO 4833: 2003	Colony counts (cfu/g)	27	NPHL, Honiara	Stomacher Incubated at 30°C for 72 hrs
E.coli (frozen tuna)	ISO 16649-2:2001	*E.coli* (cfu/g)	27	NPHL, Honiara	Stomacher Incubated at 44°C for 18 - 24 hrs
E.coli (freshly cooked tuna loins)	ISO 16649-2:2001	*E.coli* (cfu/g)	27	NPHL, Honiara	Stomacher at 44°C for 18-24 hrs
Swab Tests					
Food handlers	Millipore swab testing kit	Total coliform (cfu/swab)	3	Soltai Ltd QC laboratory	Incubated at 35°C for 24 hours
Fish tray	Millipore swab testing kit	Total coliform (cfu/swab)	1	Soltai Ltd QC laboratory	Incubated at 35°C for 24 hours
Loin cleaning knives	Millipore swab testing kit	Total coliform (cfu/swab)	1	Soltai Ltd QC laboratory	Incubated at 35°C for 24 hours
Loin moulder	Millipore swab testing kit	Total coliform (cfu/swab)	1	Soltai Ltd QC laboratory	Incubated at 35°C for 24 hours
Metal detector conveyor	Millipore swab testing kit	Total coliform (cfu/swab)	1	Soltai Ltd QC laboratory	Incubated at 35°C for 24 hours
Loin tray	Millipore swab testing kit	Total coliform (cfu/swab)	1	Soltai Ltd QC laboratory	Incubated at 35°C for 24 hours
Stainless table (loin packing)	Millipore swab testing kit	Total coliform (cfu/swab)	1	Soltai Ltd QC laboratory	Incubated at 35°C for 24 hours
Conveyor	Millipore swab testing kit	Total coliform (cfu/swab)	1	Soltai Ltd QC laboratory	Incubated at 35°C for 24 hours

Table 2 shows the summary of the total number of samples collected for chemical parameter (histamine) and microbiological (total coliform, TPC and *E.coli*) parameters analysed. It also shows the methods used to test for the parameters and where the tests were carried out. It also shows what equipment was used to macerate the tuna samples and the time/temperature used to incubate the swab samples.

In summary, a total of 54 tuna fish samples were collected for histamine analysis, this includes, 18 samples of frozen tuna fish taken during unloading from the fishing vessels to the factory, 9 frozen tuna fish samples taken at the thawing area in the processing factory and 27 samples freshly cooked tuna loins taken from the 3 sites along the processing chain in the factory.
Likewise for microbiological parameters, a total of 54 samples were collected to test for total microbial loads/TPC and *E.coli*. Eighteen (18) frozen tuna fish samples were taken during unloading (9 samples/boat) and another 9 frozen tuna fish samples taken at the thawing area. Twenty seven (27) freshly cooked tuna loin samples were taken in the processing factory.

3.3.3.1.11 Calculation of results

For enumeration of the colony counts at 30°C, ISO 7218:2007 method of calculation: general case (counting of total colonies or typical colonies) was used.

= is the number of microorganisms present in the test sample as weighted mean from two successive dilutions using the equation.
= is the sum of the colonies counted on the two dishes retained from two successive dilutions, at least one of which contains a minimum of 10 colonies;
V = is the volume of inoculum placed in each dish, in millilitres
d = is the dilution corresponding to the first dilution retained (d = 1 when the undiluted liquid product (test sample) is retained) (ISO, 2007).

<u>Results were calculated and expressed according to the following method:</u>

- <u>Site 1 Fish Acceptance (YFL20kg) – frozen tuna.</u>

- at the **first dilution** retained (10^{-1}) plate 1: 134 colonies counted;
- at the **first dilution** retained (10^{-1}) plate 2 (**duplicate**): 171 colonies counted.
- 1 ml inoculum was used

Therefore: **Average** colonies for first dilution retained (10^{-1}) = (134+171)/2 = **152.5**

- at the **second dilution** retained (10^{-2}) plate 1: 16 colonies;

- at the **second dilution** retained (10^{-2}) plate 2 (**duplicate**): 18 colonies;

  Therefore: **Average** colonies for second dilution retained (10^{-2}) = (16+18)/2 = **17**

Therefore: the number of microorganisms is 1500 or 1.5 x 10^3 per gram of product

For Millipore swab test, no template was used therefore, results were calculated on number of colonies x 18 (18 ml sterile phosphate buffer) based on the entire sample site (example, 24 cfu x 18 = 432 cfu/swab).The value is only applied to the total coliforms as indicated by the blue colour.

3.3.3.1.12 Data analysis

For the CARs issued to the fishing vessels, common themes were identified and recorded as sub-headings on the table formulated based on the CA's audit reports. CA's comments and recommendations were noted under each common theme.

All raw data from Neogen alert histamine test, total microbial loads, total coliform and *E.coli* were first recorded on data sheets, then entered onto a Microsoft Excel 2007 spreadsheet under each category for ease of data analysis. For histamine monitoring records, summary data on date of catch, source, time sets were made, time sack up, brailing started and finished, time differences, species caught, total catch/day, including temperature of the RSW, brine and salinity of the brine were entered onto a Microsoft excel spread sheet for simple comparison. Time and temperature records for histamine monitoring on board the fishing vessels were also entered on a Microsoft excel spread sheet to determine the average, standard deviation and median of the time and temperatures on different fish wells on board the fishing vessels.

The data were then copied and entered onto the SPSS version 17 data editor to be computed and analysed.Descriptive statistics were calculated to determine frequency distribution and measures of central tendency and variability were computed and analysed using the SPSS software. Graphical representations of the results are presented in section 3.3.3.1.11.

3.3.3.1.13 Results

Under this section, there are discussion comments that would traditionally not appear here. Given the complex nature of mixed methods research, with numerous sections it was considerd appropriate to make preliminary explanatory comments close to the tables and figures where the data is displayed.

a) Histamine monitoring records

Table 3: Summary findings of the review of histamine monitoring on board fishing vessels

Vessel - Solomon Pearl							Species		
Date of catch	School Ass	Time Set	Time Sack up started	Time brailing started	Time brailing finished	Time difference	SJ (ton)	YF (ton)	Total catch/day (ton)
Vessel - Solomon Emerald									
7/9/2010	School fish	1410 hrs	1610 hrs	1635 hrs	1705 hrs	1.10 mins	6	54	60
8/9/2010	School fish	1740 hrs	1930 hrs	2020 hrs	2040 hrs	20 mins	0	10	10
9/9/2010	School fish	1405 hrs	1600 hrs	1600 hrs	1610 hrs	10 mins	0	5	5
10/9/2010	School fish	1810 hrs	2020 hrs	2110 hrs	2120 hrs	10 mins	1	4	5
11/9/2010	FAD (Payao)	0545 hrs	0750 hrs	0825 hrs	0920 hrs	1.35 mins	15	10	25
12/9/2010	School fish	1433 hrs	1640 hrs	1720 hrs	1728 hrs	8 mins	0	10	10
13/9/2010	FAD (Payao)	0540 hrs	0730 hrs	0820 hrs	0945 hrs	1.25 mins	48	32	80
14/9/2010	FAD (Payao)	0540 hrs	0745 hrs	0805 hrs	0820 hrs	15 mins	8	12	20
15/9/2010	FAD (Payao)	0532 hrs	0738 hrs	0815 hrs	0840 hrs	25 mins	21	4	25
16/9/2010	FAD (Payao)	0526 hrs	0735 hrs	0805 hrs	0852 hrs	47 mins	48	17	65
17/9/2010	FAD (Payao)	0525 hrs	0720 hrs	0805 hrs	0820 hrs	15 mins	24	6	30
Solomon Pearl									
16/9/2010	School fish	1320 hrs	1525 hrs	1545 hrs	1715 hrs	2.30 hrs		50	50
17/9/2010	FAD (Payao)	0540 hrs	0800 hrs	0905 hrs	0945 hrs	40 mins	19	6	25
18/9/2010	FAD (Payao)	0545 hrs	0810 hrs	0855 hrs	0935 hrs	1.20 mins	45	15	60
19/9/2010	FAD (Payao)	0535 hrs	0730 hrs	0805 hrs	0835 hrs	30 mins	5	15	20
20/9/2010	FAD (Payao)	0555 hrs	0815 hrs	0835 hrs	0850 hrs	25 mins	4	6	10
24/9/2010	FAD (Payao)	0525 hrs	0820 hrs	0850 hrs	0915 hrs	1.25 mins	13	7	20
25/9/2010	FAD (Payao)	0530 hrs	0730 hrs	0800 hrs	0830 hrs	30 mins	13	7	10
26/9/2010	FAD (Payao)	0535 hrs	0535 hrs	0730 hrs	0750 hrs	20 mins	2	13	15
28/9/2010	FAD (Payao)	0530 hrs	0530 hrs	0825 hrs	0850 hrs	25 mins	34	11	45
29/9/2010	FAD (Payao)	0525 hrs	0730 hrs	0805 hrs	0900 hrs	55 mins	8	2	10

Source: (Soltai, 2010b).

Table 3 shows the summary findings of the systematic review of the histamine monitoring on board the NFD Ltd fishing vessels. The above table shows the source (where the fish were caught from school fish or FAD), it also shows the time when the set (net) was made, time sack up, brailing, started and finished. The species of tuna caught (whether skipjack tuna or yellow fin) was also recorded including the estimated total catch/set made.

b) Compliance records

Table 4: Summary findings on review of the CA audit reports and interviews conducted with the CA auditors

Frequency of Audits	Implementation of HACCP	Understanding of HACCP principles	Area needs improvements
Quarterly audits (4 times/year)	NFD Ltd has a well documented HACCP manual	Off shore personnel have good understanding of the HACCP principles	Proper keeping of the records
	Maintaining HACCP is costly for NFD Ltd	Problem with maintaining/keeping proper records	Proper monitoring of activities on board the fishing vessels
	Doing well but needs improvement	Need further training on HACCP especially for the fishermen	Need to implement what is documented
			Need a lot of training and awareness on HACCP

Table 4 shows the common themes derived in the review of the CA audit records and interviews conducted with some (n=3) of the CA auditors. The CA conducts quarterly audits of NFD Ltd fishing vessels, a total of four audits per year.

c) Median temperatures of catching wells

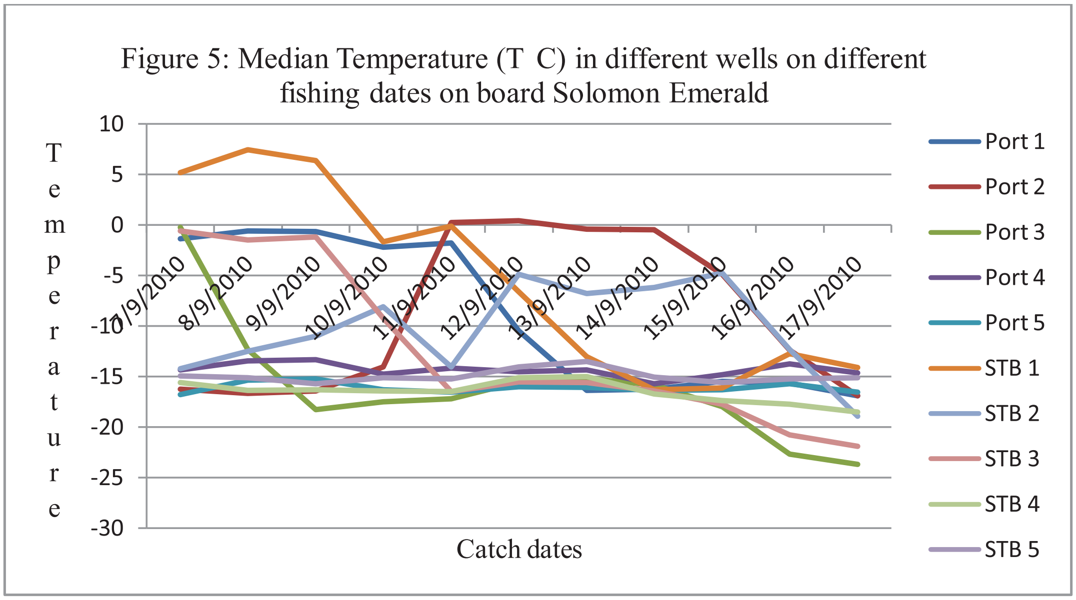


Figure 5: Shows the median temperature of RSW and brine monitoring on board Solomon Emerald.The graph reveals that the temperature for all wells from day 1 (7.9.10) to the final day (17.9.10) falls within the acceptable ranges (0°C for RSW) and < -9°C for brine. However, high temperature of RSW at STB 1 (5.2°C) on the 10.9.10, 7.45°C on the 11.9.10, and 6.4°C on the 12.9.10 indicates that the RSW was stored in the fish wells at normal temperature of the fishing vessel without the refrigeration system on. This indicates that there were no fish stored in the well (STB 1) until the fourth day of fishing (10.9.10) at which point the RSW was maintained at -1.65°C in preparation to receive fish. Low temperatures of fish wells in port 2 (-16.25°C), port 4 (-14.35°C), port 5 (-16.75°C), STB 2 (-14.2°C), STB 4 (-15.6°C) and STB 5 (-14.9°C) at the start of the fishing trip indicated that there were left over fish from the previous trip which were not well frozen (approximately 185 tons) stored in brine in the wells on board the fishing vessel as per the Chief Engineers log sheet. The 3 days in port taken to freeze the fish wells, further enhances the temperature of the fish prior to unloading as shown in the above graph. The temperature for all fish wells prior to unloading ranges from – 16.9°C for port 1, port 2 (-16.9°C), port 3 (-23.7°C), port 4 (-14.6°C) and port 5 (-16.5°C). STB 1 (-14.1°C), STB 2 (-18.9°C), STB 3 (-21.9°C), STB 4 (-18.5°C) and STB 5 (-15.1°C). The brine salinity for Solomon Emerald ranges from 20-23%.

d) Brine salinity and temperature

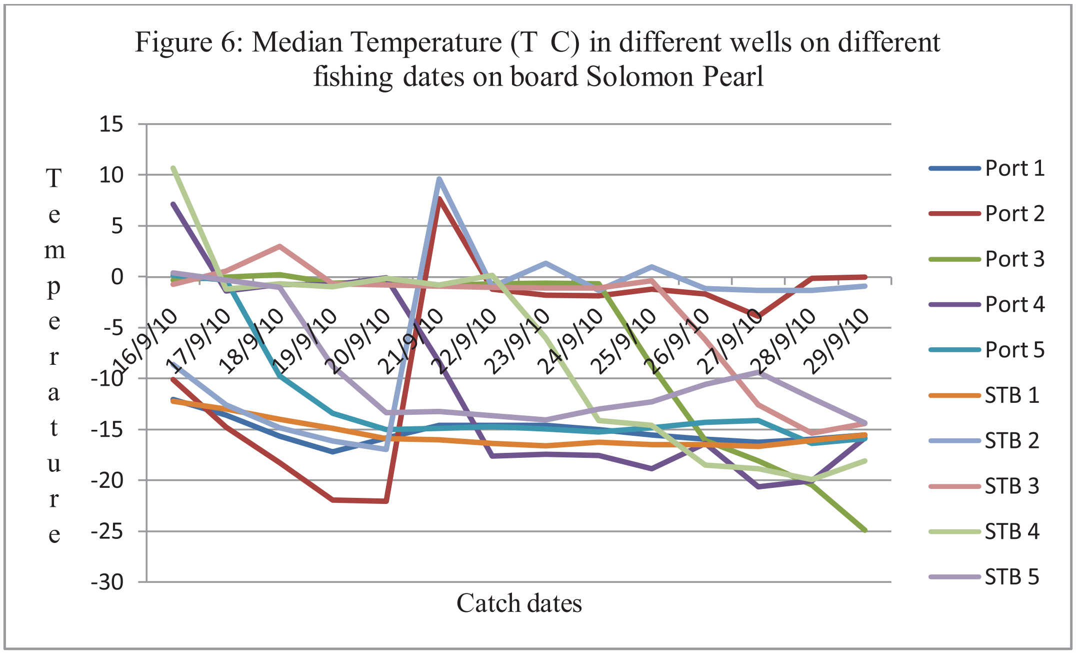


Figure 6: Shows the median temperature of the brine and RSW in the different wells on board the fishing vessel. There are a total of 10 wells on board Solomon Pearl, 5 on the port side and 5 on the starboard side of the vessel.Temperature monitoring on board the fishing vessels is done on a four hourly basis per day.The trend revealed that temperature monitoring falls within acceptable ranges as per the company's HACCP manual, i.e., RSW temperature at 0°C- 3°C prior to receiving fish (NFD, 2008). However, the Chief Engineers, based on their experience, may have different ways of freezing their fish with slight differences on the RSW temperature. For example, some engineers would prefer to keep their RSW at -2°C to -1°C prior to receiving fish to quickly stabilize the temperature of the tuna prior to transferring the brine. The slight increase of temperature for port 4 (7.15°C) and STB 4 (10.7°) indicated that new fish were stored in the wells on the first day of the fishing trip. Fresh tuna fish, depending on the condition and temperature of the sea might come in with temperatures ranging from 28°C - 31°C, thereby increasing the RSW even though it is maintained at -2°C to 0°C prior to receiving fish.

The low temperature of wells on port 1 (-12°C), port 2 (-10.1°C), STB 1 (-12.2) and STB 2 (-8.6) indicates that there were left over fish from the previous trip on board the fishing vessel (approximately 70 tons), because the fish was not frozen to the required temperature. STB 2 (-8.6) could indicate the temperature of the brine kept on board as brine temperature should be maintained at or below -9°C (NFD, 2008). The slight increase of temperature in port 2 (7.65°C) and STB 2 (9.6°C) on the 21.9.10 possibly indicates a faulty probe in the wells on that particular day, or that new fresh tuna fish was loaded into the two wells which increased the temperature of the RSW. Within 24 hrs the temperature quickly stabilizes back to -1.25°C and -1°C respectively which falls within the acceptable RSW temperature in the wells. The graph further shows that the temperature readings for all wells from 22.9.10 to the last day (29.9.10) of the fishing trip falls within acceptable ranges as far as histamine control and monitoring on board the fishing vessels are concerned - Port 1 (-15.55°C), port 2 (-0.05°C), port 3 (-24.9°C), port 4 (-15.8°C) and port 5 (-15.9°C). STB 1 (-15.55°C), STB 2 (-0.95°C), STB 3 (-14.4°C), STB 4 (-18.05°C) and STB 5 (-14.35°C). High temperatures in port 2 (-0.05°C) and STB 2 (-0.95°C) indicate that fish in the wells were freshly caught and freezing continued until it reached - 9°C or less prior to unloading. The brine salinity for Solomon Pearl ranges from 20-24%.

e) Histamine content

Table 5: Shows the histamine content (ppm) (n = 54).

Histamine Content					
Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
< 10 ppm	< 10 ppm	< 10 ppm	< 10ppm	< 10 ppm	< 10 ppm

Composite samples (9 samples/composite) were used to test for histamine. A total of 54 samples were collected, therefore, 6 composite samples were tested for histamine. All readings for histamine content were < 10 ppm

f) Total microbial loads/TPC

Table 6: Mean, median, minimum and maximum total microbial load (TPC), expressed as cfu/g, from frozen tuna using stomacher and homogenizer to macerate the samples

		Stomacher	Homogenizer
N	Valid	9	9
	Missing	0	0
Mean		1731.11	2643.67
Median		770.00	220.00
Minimum		230	0
Maximum		5800	16000

Table 6 shows the mean and median values of total microbial loads (cfu/g) using the stomacher and homogenizer to macerate the frozen tuna samples obtained during unloading from the fishing vessels.Due to breakdown of the stomacher machine to macerate tuna samples to analyse microbiological parameters, the homogenizer was used instead. The results show that the total microbial loads present in frozen tuna samples using the stomacher to macerate the tuna samples ranges from 230 - 5800 cfu/g and the median is 770. Likewise, the value for frozen tuna samples using the homogenizer to macerate the tuna samples ranges from 1-16,000 cfu/g, and the median is 220.

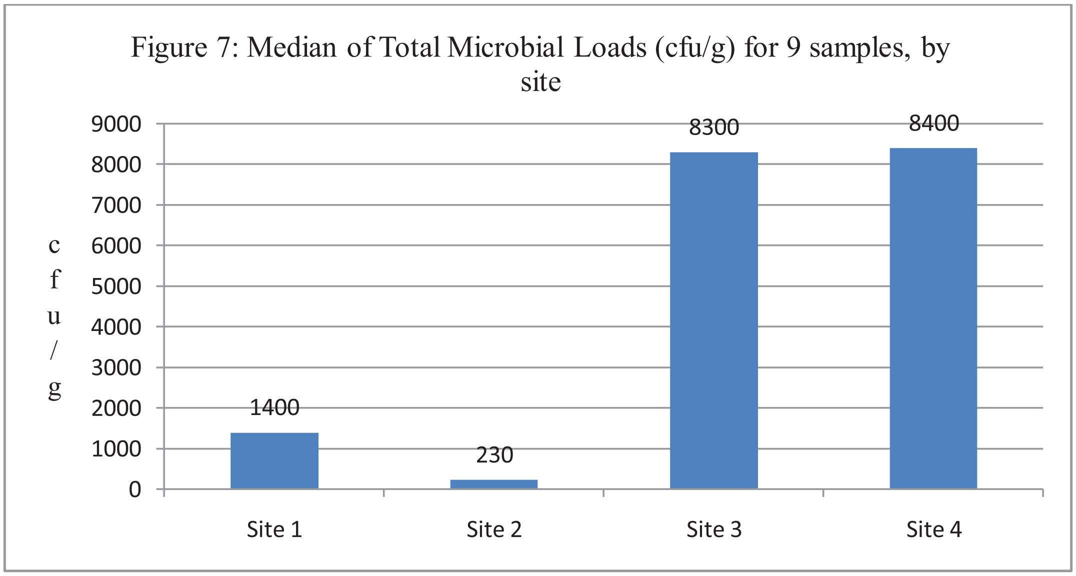


Figure 7: Shows the median value of the total microbial loads for the nine samples between the four sites in the processing factory. The highest median value 8400 cfu/g was recorded at site 4, the loin packing area. Site 3 recorded a median value of 8300 cfu/g, site 1 1400 cfu/g and site 2 has the least median value of 230 cfu/g. Site 1, the thawing area, has a greater median value 1400 cfu/g, probably because the samples were taken before processing. Site 2 has low value 230 cfu/g because samples are taken after cooking. High values were recorded later in the processing line at sites 3 (8300 cfu/g) and 4 (8400 cfu/g).The highest value samples were recorded at the end of production, prior to loin packing.

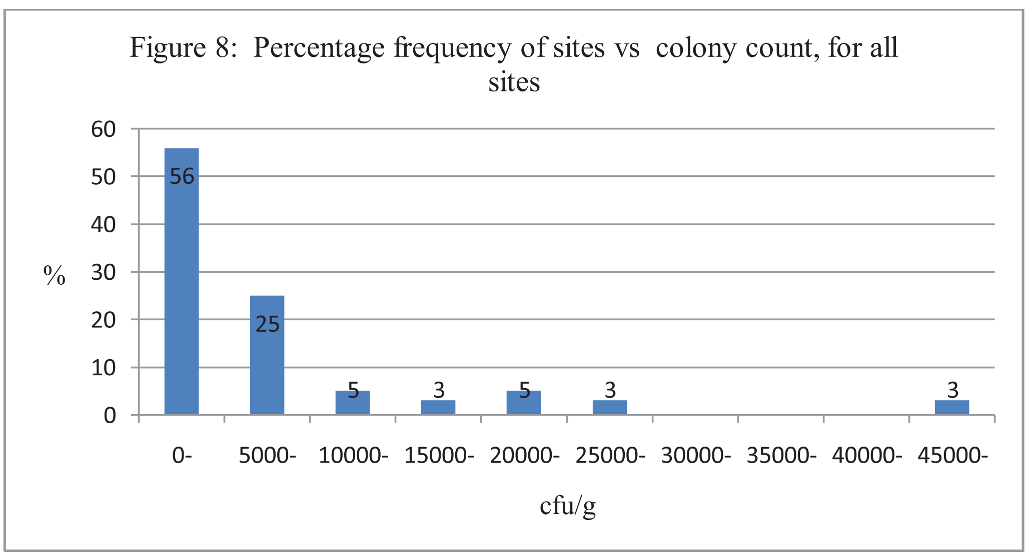


Figure 8: Shows the frequency distribution of the total microbial load (cfu/g) for all sites for the total 36 samples taken. Dividing the distribution of the colonies (cfu/g) within the range of 5000 cfu/g, there is uneven distribution of cfu/g within the 36 samples. Most (81%) of the values were within the range of 0 - 10000 cfu/g.

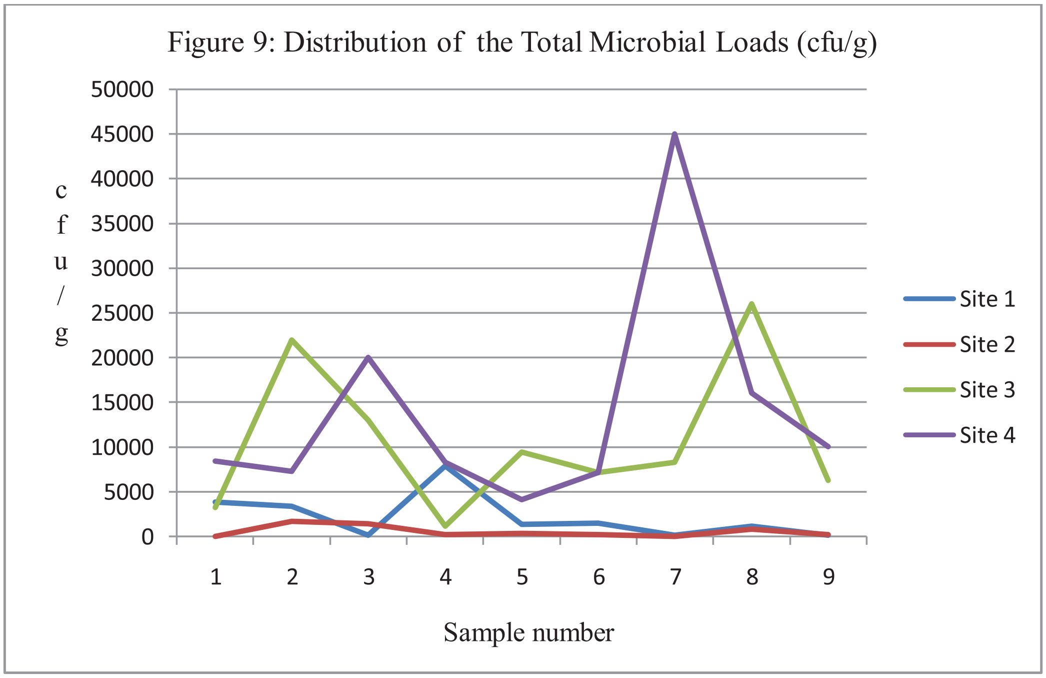


Figure 9: Shows the trend of the total microbial load (cfu/g) at 30°C among the sites for the nine samples taken.The line graph shows no obvious relationship of the trend/distribution of microbial contamination among the sites for the nine samples taken. However, there may be some correlation between sites 2 & 3.

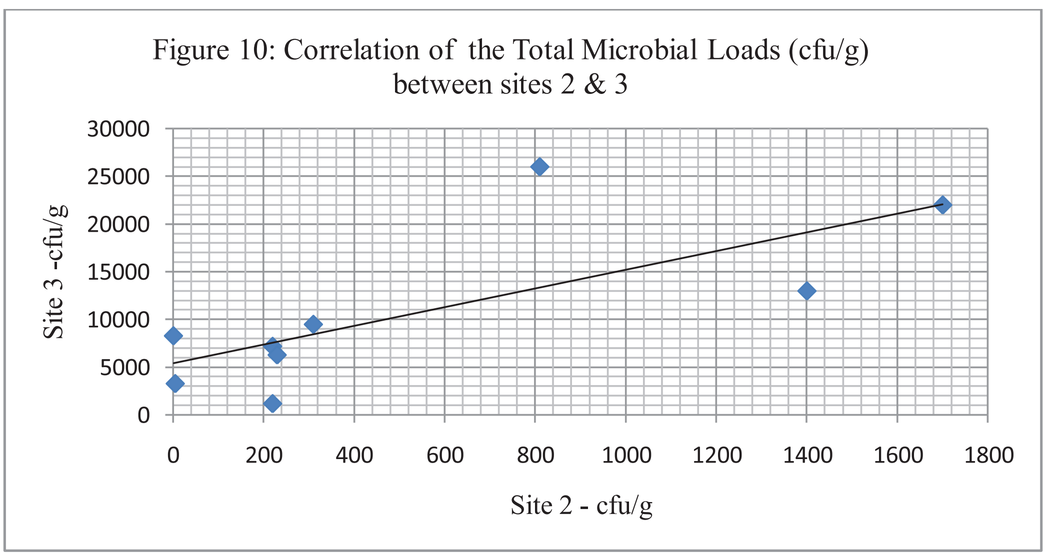


Figure 10: Shows the correlation between sites 2 and 3.The correlation between the results for sites 2 & 3 when the line of best fit is drawn (R^2 Linear =0.538) is moderate. The unmarked points of total microbial loads between site 2 (after cooking) and site 3 (processing line) when the line of best fit is plotted could be due to varying ranges of the values, site 2 from 1-1700 cfu/g and site 3 ranging from 1200 – 26,000 cfu/g. The reason why R^2 is less than 1, is because there is not a perfect correlation between the two sites and this may simply be due to samples not taken on the same day.

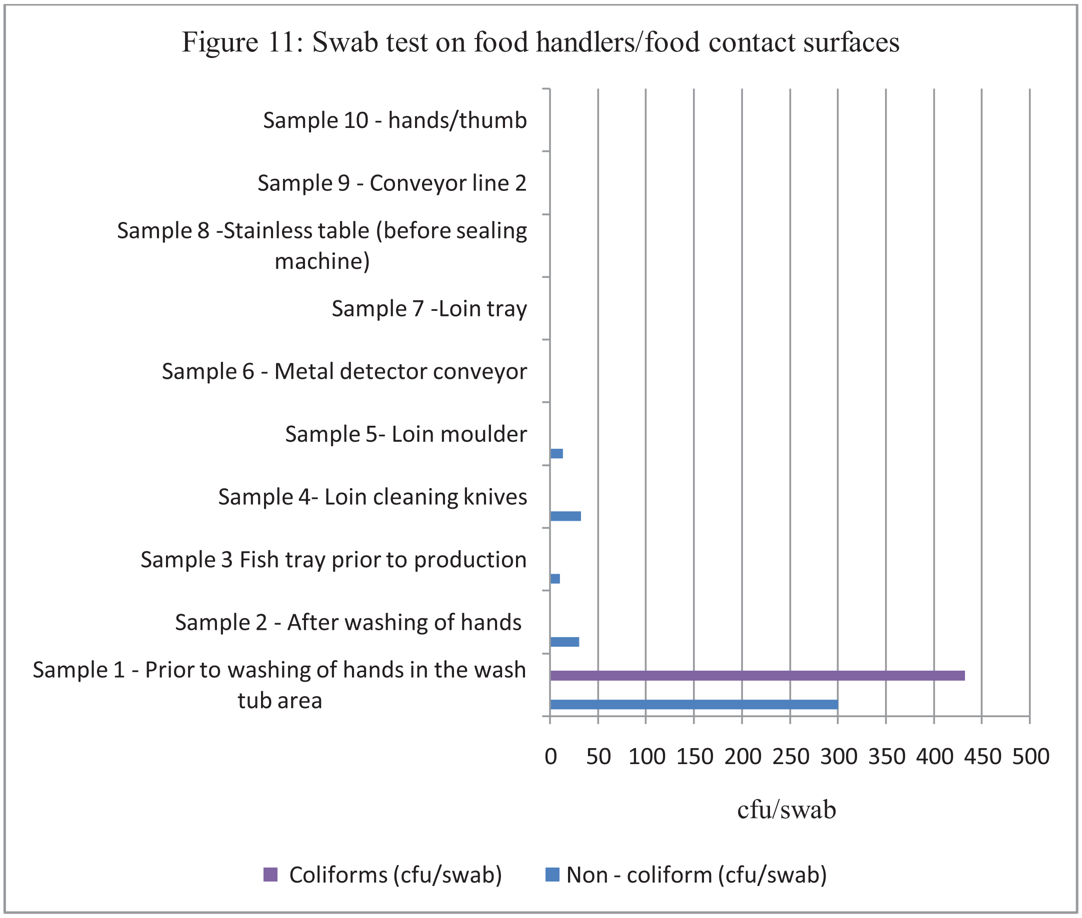


Figure 11: Shows the result of the swab test for total coliforms incubated at 35°C conducted on food contact surfaces and food handlers. Sample 1 (food handlers' thumbs) shows a high number of total coliforms 432 cfu/swab and non coliform organisms 300 cfu/swab prior to washing of hands. Sample 2 (after washing of hands) showed zero reading for total coliform and a high number, 30 cfu/swab non coliform microorganisms at 35°C.

Results for β- glucuronidase-positive *E.coli* colony count at 44°C showed all (n=54) tuna fish samples contained less than 1cfu/g (refer appendix XII).

3.3.3.1.14 Discussion

With reference to the review of the Chief Engineer's histamine monitoring records (refer to table 2), it is clear that NFD Ltd fishing vessels are complying with the requirements of the EU Regulation EC 853/2004 and the Pure Food (*fishery products*) Regulation 2005.The Chief Engineers were up to date with their histamine monitoring records,which gave a good indication that fish handling and storage on board NFD Ltd fishing vessels is well managed. On the same note, review of the records showed that, time and temperatures, which are critical determinants in the control of histamine on board fishing vessels, were well managed. Time difference (refer to table 3) between when brailing started and was completed falls well below the maximum of 6 hours, which is deemed to be the critical time for tuna fish to be regarded as suspect as noted by

Burns (1985). The RSW temperature and the brine temperature, including the salinity (%) of the brine on board the fishing vessels falls within the acceptable ranges and requirements as stipulated in the Solomon Islands Pure Food *(fishery products)* Regulation 2005 ("Pure Food (*fishery products*) Regulation," 2005) and other international requirements such as FDA requirements (FDA, 2001) to control histamine formation on board fishing vessels (refer to figure 5 & 6). Slight variance in brine salinity (%) indicates different approaches used by the Chief Engineers when freezing their fish, based on their experience. It is common practice on board the fishing vessels that fish that are not frozen to the required temperature will be left on board until the next unloading. This normally happens with fish that are caught prior to unloading or if the fishing vessel encounters mechanical problem which subsequently affects the refrigeration system. This is one of the reasons why there are low temperature readings of the fish wells prior to fishing on board the fishing vessels (refer to figure 5 & 6).

Maintaining GMP/SSOP on board fishing vessels is important as it is the primary source whereby the tuna products come in contact with food safety hazards. The concept of HACCP is all about minimising potential risks from the source to product shipment.Therefore it is necessary to ensure that pre-requisite programs such as the GMP/SSOP are strictly enforced in the fishing vessels to help minimise and control food safety hazards (physical, biological and chemical) and risks prior to processing. The success of the HACCP food safety system relies mostly on compliance and the effective implementation of the pre-requisite programs (GMP/SSOP) (Ouma, 2002). In terms of implementation of HACCP, NFD Ltd has a well documented HACCP manual but needs improvement. Maintaining HACCP is costly for NFD Ltd. In terms of understanding of the HACCP principles, the review and interview conducted revealed that NFD Ltd offshore based personnel have a good understanding of the HACCP principles, but there is a great need to train the fishermen on board the fishing vessels about HACCP principles. The review and informal interviews conducted highlighted that NFD Ltd has a problem with maintaining/keeping proper records of the work carried out to comply with their HACCP manual, EU Regulations (EC 852/2004, EC 853/2004 & EC 854/2004) and the Solomon Islands Pure Food (*fishery products*) Regulation 2005.

In terms of the areas that need improvement, the review showed that there is a need to keep the records properly and monitor the SSOP/GMP on board the fishing vessels. NFD Ltd also needs to implement what is documented in their HACCP manual and there is a great need to conduct further training and awareness talk onboard the fishing vessels on HACCP principles including SSOP/GMPs.

Scombrotoxin (histamine) formation, which is a major food safety hazard associated with consumption of tuna, mahi mahi and blue fish, is commonly formed as a result of time and temperature abuse on board the fishing vessels during catching (FDA, 2001). Histamine-forming bacteria are capable of growing and producing histamine over a wide temperature range. Growth is more rapid, however, at a high abuse temperature of 21.1°C than at moderate abuse temperatures of 7.2°C.Growth is particularly rapid at temperatures near 32.2°C. Histamine is more commonly the result of high temperature spoilage than of long term, relatively low temperature spoilage (FDA, 2001).

The major health threat from histamine is that, once the enzyme histidine decarboxylase has been formed, it can continue to produce histamine in the fish even if the bacteria are not active. Freezing may inactivate the enzyme-forming bacteria or cooking could inactivate the enzyme and the bacteria, but the problem lies in the fact that once histamine is formed, it cannot be eliminated or reversed by heat (including retorting for canned tuna products) or freezing (Burns, 1985; FDA, 2001). Therefore, the only way to control the formation of histamine is to ensure that time and temperature on board the fishing vessels are strictly controlled (refer figure 12). The EU EC 853/2004 requirement as far as time and temperature are concerned, is that tuna fish should be placed in chilled seawater or RSW at 0°C for 16 hours (European Parliament, 2004a).

Other factors that could influence the time necessary for the backbone temperature of a fish to equilibrate with RSW temperature are the loading density (tonnage caught/day) and the size of the fish, as the interior of larger fish cools more slowly (Burns, 1985). For example, large tuna (> 20kg) that are not eviscerated before on board chilling should be chilled to an internal temperature of 10°C or less within 6 hours of death. Similarly, fish exposed to air or water temperatures above 28.3°C , or large tuna (> 20kg) that are eviscerated before on board chilling, should be placed in ice (including packing the belly cavity of large tuna with ice) or RSW or brine at 4.4°C or less within 6 hours of death (FDA, 2001). Therefore, rapid chilling of fish immediately after death is the most important element in any strategy for preventing the formation of scombrotoxin (histamine), especially for fish that are exposed to warmer waters or air and for large tuna (> 20kg) that generate heat in the tissues of the fish following death (FDA, 2001). FDA recommended time for fish to be stored in the RSW prior to brining is not more than 5 days (refer to figure 12) (Burns, 1985).The timing of these events is critical as prolonging the time and temperature of the fish in the net for more than 6 hours enhances histamine formation and the fish would then be regarded as suspect (Burns, 1985).

This would also minimise the risk of contaminating fishery products with chemical contaminants such as oil spills, fuel, grease and physical hazards such as timber chips or metal fragments coming in contact with the tuna fish. Maintaining the SSOP/GMP would also lessen microbiological hazards resulting from fish decomposition due to time and temperature abuse and contamination due to cross contamination from the food handlers. The systematic review of the histamine monitoring records on board the fishing vessels revealed that NFD Ltd fishing vessels are in compliance with the EU directives (EC 853/2004 and EC 854/2004) and the Solomon Islands Pure Food *(fishery products)* Regulation 2005 and other international requirements such as the FDA standards as far as histamine control is concerned. However, what NFD Ltd needs to further strengthen is the implementation of what is documented in their HACCP food safety system. For example, it clearly spells out in the company HACCP manual that, an internal verification (audit) to validate and verify SSOP/GMPs on board the fishing vessels should be conducted at least once a year (NFD, 2008). To what extent NFD Ltd has complied and carried out an internal audit of their documented HACCP manual is not known, and this could be regarded as non compliance on their part (J.Reynolds, personal communication, October 28, 2010).

The process in the Solomon Islands as per the Solomon Islands Pure Food *(fishery products)* Regulation 2005 and EU Regulations EC 852/2004, EC 853/2004 and EC 854/2004 requires all fishing companies to be registered by the CA, a similar system to that used by the New Zealand Food Safety Authority (NZFSA) that requires all limited processing fishing vessels to be registered under NZFSA, the operator must develop a documented system for operating a regulated control scheme (RCS) and the RCS must be verified by an external verifier (NZFSA, 2004). Similarly, the HACCP certification of food services in Philippine interisland passenger vessels imposed by the Philippine Bureau of Quarantine and International Heath Surveillance (BQIHS), could also be established to address similar issues on maintaining GMP/SSOP on board vessels transporting fishery products or food products to be exported internationally and sold locally (Azanza, 2006).

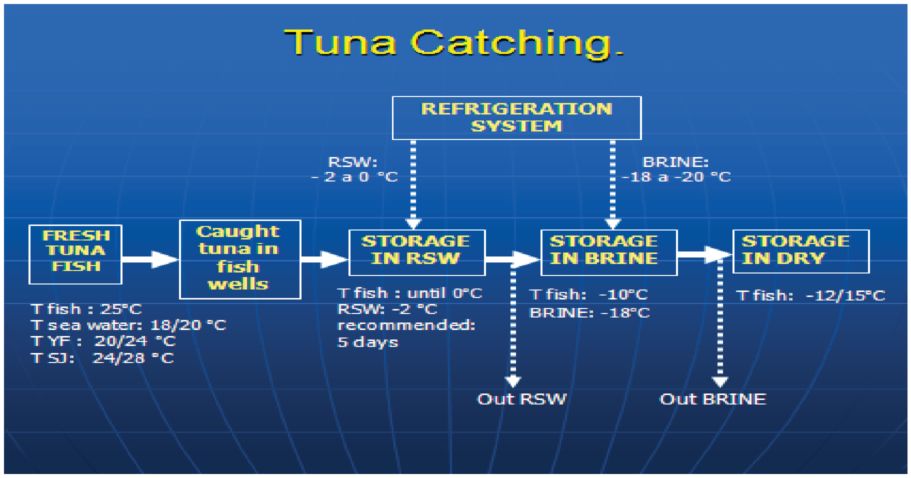


Figure 12: Flow diagram showing how to maintain GMP onboard fishing vessel (purse seiners) to control histamine formation.Source: (Mitrovic, 2006).

The histamine results show all samples were < 10 ppm (refer to table 5). The results when compared to the EU acceptable limits of m = 100 mg/kg (100 ppm) acceptable limit and M = 200 mg/kg (200 ppm) acceptable upper limit, (amounts exceeding M would be rejected) (European Parliament, 2005) falls well below acceptable limits. The value when compared to the Solomon Islands Pure Food (*fishery products*) Regulation 2005 requirement for histamine which states that (a) "the mean value must not exceed 100 ppm and (b) two samples may have a value of more than 100 ppm but less than 200 ppm" ("Pure Food (*fishery products*) Regulation," 2005, p. 147) falls well below the acceptable standards.

The results do not really show any association between catching method and histamine content. This could be due to low tonnage (< 80 tonnes) caught per trip or because the GMP on board the fishing vessels were well monitored. The other reason why it's difficult to draw any association is because the Neogen alert histamine tests do not really indicated quantitative data other than qualitative data. Histamine formation is more closely associated with big sets made (> 80 tons) and sets made on school fish than small sets (< 80 tons) (Burns, 1985).Fish caught from schooling fish are prone to trigger histamine formation quicker than fish caught from FAD devices. Schooling fish move vigorously, unlike fish caught in the FAD, where they circle slowly below the FAD when sets are made.

A number of microbial tests of fish and fish products were conducted by Soltai Ltd company and sent to an Australian laboratory (Symbio Alliance) for validation of their SSOP/GMP and internal verification to check that the microbiological limits conform to buyer specification

(TMI, 2010), and the EU microbiological criteria for food stuffs EC 2073/2005 are satisfactory (European Parliament, 2005). Microbial indicators are often employed to assess food safety and sanitation (Samakupa, 2003). Due to break down of the spectrophotometer used to test for histamine, quantitative histamine tests were not able to be conducted to determine any relationship between microbiological build up and histamine formation between sites in the processing chain. Sampling procedure was conducted in accordance with the routine standard operation procedure of the company.

However, the TPC results show interesting trends among the different sites, that in general, microorganisms were already present at the first sampling point (thawing area) including all other steps in the processing chain (refer to figure 7). Figure 7 shows a disturbing trend of total microbial load within the processing chain in the factory. The reason site 1 (fish thawing area before cooking) has higher median value (1400 cfu/g) than site 2 could be due to cross contamination when handling frozen tuna fish in the cold storage. Site 2 (cooked fish, prior to first cleaning) has a low median, because the tuna loins undergo intensive cooking at high temperature (98°C) and were just taken from the misting room after cooking and had been considerably less handled prior to reaching sites 3 & 4. By the time the tuna loins reached sites 3 & 4, it is likely that more people handling the tuna loins have contaminated them. In addition, a likely cause is that food contact surfaces such as trays, cleaning knives as well as food handlers' hands were not cleaned properly (refer to figure 11).

It is possible that contamination may have taken place before the fish were brought into the factory for processing (refer to table 6). On the other hand, one could also argue that contamination of tuna by microorganisms could have taken place in the processing chain since some processing equipment and food handlers thumbs were tested positive for coliforms (refer to figure 11). The presence of microorganisms on frozen tuna samples (refer to table 6 and site 1 figure 7) is clear evidence that the fish were also contaminated by food handlers or food contact surfaces prior to processing.

There is cause for concern, even though the total microbial load values are within the acceptable limits described in International Commission on Microbiological Specification for foods (ICMSF) for TPC, which recommend microbiological limits for fresh/frozen fish and precooked breaded fish of m (acceptable level) = 5×10^5 (500,000 cfu/g) and M (unacceptable level) = 5×10^7 (50, 000 000 cfu/g) respectively (ICMSF, 1986), the presence of a significant number of microorganisms at all four sites indicates that there is potential risk that tuna products can be contaminated by food handlers. The ICMSF recommended limits for seafoods as far as *E.coli* is concerned is m = 11 cfu/g and M = 500 cfu/g respectively (ICMSF, 1986).

However, taking into consideration the international acceptable limit of cooked fishery products of 100,000 cfu/g (ICMSF, 1986), which are recognised by most regulatory agencies, the value of the total microbial loads tested at Soltai Ltd are acceptable, but are at the high end of the range.Soltai Ltd should therefore not be complacent and should make greater effort implementing the documented HACCP food safety system in the factory. The results indicated that, although Soltai Ltd does have a potentially effective HACCP food safety system in place, it is not effectively implemented, and there is high risk of cross contamination arising from poor personal hygiene by the food handlers or because the SSOP/GMPs in the factory are not effectively maintained. There is a need to strengthen the implementation of the SSOP/GMPs and personal hygiene in the factory to minimise cross contamination of the tuna products.

Numerous factors may have contributed to the lack of consistency in the trend/distribution data of the total microbial loads and (*E.coli*) (refer to figure 9). It took about a month for the tuna loin samples to be analysed at the Honiara laboratory. This was unavoidable. The samples were stored in the freezer at -18°C which could have killed some of the microbes, and affected the results. However, it is presumed that some of the bacteria survived freezing and thus gave results for total microbial load and also *E.coli* counts. If anything these will be on the low side, but are still indicative of contamination. In addition the samples were taken on different days; it is possible that the water supply used for washing/cleaning the food contact surfaces after production was not properly chlorinated, or even if the water source was chlorinated properly cross contamination could be caused by those engaged in the cleaning process. Cleaning/washing of the food contact surfaces is normally done in the night after a day's production, and there is a possibility that due to poor supervision, those engaged in the cleaning process did not wash their hands properly before engaging in the cleaning process.
The other reason could be that, cleaning was not done properly; or the detergent used was not being mixed properly, or could be due to negligence. Incidents have been reported where left over fish or loins were found on the conveyors after washing/cleaning. Without further more focused research it may be impossible to say for certain what caused the contamination. The important thing is that some contamination has occurred and it reflects a break down in food safety.This is where training on the importance of SSOP/GMP is paramount in a tuna processing factory.

Figure 11 showed the distribution of total coliforms on food contact surfaces and food handlers using the Millipore swab testing kit. The results showed significant numbers of microorganisms on food handlers thumbs which indicates that greater effort and consistent proper supervision is needed to ensure that the standard of hygiene is maintained in the factory at all times.The rationale for conducting sampling on food handlers and food contact surfaces, is because, there is evidence in the literature that cross contamination can occur from food handlers' and food contact surfaces (Ouma, 2002; Ravin, et al., 2003; Samakupa, 2003). Also, this will determine the effectiveness of the SSOP/GMP's as stipulated in the company HACCP food safety system. Presence of a significant number of total coliforms indicates unhygienic condition that the company SSOP/GMP were not carried out effectively.

Sample 1 (prior to washing of hands) and 2 (after washing of hands) shows a disturbing trend. Though the samples were not representative of food handlers, because there were only 2 food handlers swabbed, the presence of a significant number of coliforms on the food handler's thumb after washing of the hands indicated that proper training is needed on basic personal hygiene measures, especially how to thoroughly wash, rinse and dry hands. Though detergents or sanitizers may be provided to wash hands, unless the workers fully understand how to wash, rinse and dry their hands properly, then it does not serve the purpose, and there will be a high possibility for cross contamination of the tuna products.

Similar studies conducted by Reij, Den Aantrekker and Microbio (2004), attributed poor hygiene, particularly due to deficient or absence of hand washing, as the causative mode of transmission. The study further revealed that bacterial contamination in processed seafood in many cases was due to unclean, insufficiently or inadequately cleaned processing equipment (Reij, et al., 2004). Furthermore, studies conducted by Montville, Chen and Schaffner (2002), have similarly concluded that, during handling and preparation, bacteria may be transferred from contaminated hands of food workers to food, and subsequently to other surfaces including food contact surfaces. In his studies to determine effective hand washing in retail food operations Snyder (1998) concluded that low infectious doses from organisms such as *Shigella* and the pathogen *E.coli* were found to be linked to hands as a source of contamination.

In general, when a healthy fish is caught, the flesh in its natural state is sterile (Samakupa, 2003), as its immune system prevents bacteria proliferating easily, whereas after death the fish's immune system collapses allowing easy access of micro-organisms into the flesh (Huss, et al., 2000). Indeed fish and other free swimming marine animals do not normally carry organisms particularly of mammalian microflora such as *E.coli*, faecal coliforms and enterococci. The presence of human enteric organisms on seafood is a clear evidence of contamination from a terrigenous source (ICMSF, 1986).

Along with the analysis of total microbial loads and *E.coli* on fish products in the processing chain, it is also important to evaluate actual microbiological presence of frozen tuna at the landing site and food contact surfaces in order to check the effectiveness of the HACCP food safety system in place and to appraise performance of the critical control points, good hygienic practices and SSOPs (Jacxsens, et al., 2009). The microbial quality of surfaces has been identified as a useful indicator for control of the critical points related to the procedures of cleaning and disinfection (Legnani, Leoni, Berveglieri, Mirolo, & Alvaro, 2004). Furthermore, the microbiological analysis of food contact surfaces (refer to figure 11) could indicate the actual status of the hygiene design of equipment and facilities and actual specificity of the sanitation program, while the swab tests of food handlers thumbs will indicate the actual performance of personnel hygiene practices (Jacxsens, et al., 2009). It is in this regard that microbiological tests for total coliforms were conducted on food handlers' thumbs and food contact surfaces in the factory.

Comparing the β-glucuronidase-positive *E.coli* values for all the samples of less than 1 cfu/g to the national standard for thermotolerant coliform incubated at 44°C for fishery products (solid medium) as per the Solomon Islands Pure Food (*fishery products)* Regulation 2005, m = 10 cfu/g (limit below which all results are considered satisfactory) and M = 1000 cfu/g (acceptability limit beyond which the results are considered unsatisfactory), β-glucuronidase-positive *E.coli* values at Soltai Ltd fall within acceptable ranges.

One of the difficulties observed and noted in the factory is that, even though the employees had many years of experience (refer to figure 14), they do not always comply with hygienic practices probably because they could have created old habits that have enabled them to produce "safe" food products (Luning & Marcelis, 2009). Similar sentiments were echoed by Angelillo, Viggiani, Rizzo and Bianco, 2000; Clayton, Griffith, Price and Peters, 2002; and Sneed, Stronhbehn and Gilmore, 2004 who stated that even when food service workers demonstrate good knowledge of food safety or have a positive attitude towards food safety, they do not always comply with safe preparation practices or improve in their hygiene behaviour. In addition, Panisello and Quantick (2001) identified constant turnover of employees as a barrier to the proper implementation of the HACCP system, as employees need time and training in order to fully comprehend and use the system.

Furthermore, a study conducted by Bas, Yuksel and Cavusoglu., (2007) in Turkey identified lack of knowledge about HACCP and other food safety programs as the main barriers for food safety in food business. Bas, et al. went on to state that, lack of prerequisite programs and inadequate physical condition of the facility were also barriers. It also includes lack of training programs, on both basic food safety and HACCP principles to support implementation of the prerequisite programs and HACCP in food business (Bas, et al., 2007).

3.3.3.2 Phase three – survey research

3.3.3.2.1 Sample size and selection of participants

Prior to recruitment of study participants involved in the survey research, permission was obtained from the General Manager, to conduct a 10-15 minute open forum with Soltai Ltd factory workers. This was done in the company mess room during a lunch break.

This was a deliberate strategy, so that the factory workers were made aware of my presence in the factory, and the nature of my research, and what their involvement might be. It was stressed that they were not obliged to take part in the study, even if approached – as they had the right to decline.This was to allow staff time to reflect on whether or not they wished to take part, should they be approached later on.When they were selected to participate in the study, they were already aware of the aim and objectives of the proposed research. Study participants were randomly selected from the list of staff names provided.

Once they understood the purpose of the survey, and qualitative interviews which for some were to follow, and agreed to participate, a letter and information sheet plus the survey questionnaire were posted to the 70 chosen participants. Eleven (11) extra participants were randomly selected above the original 59 participants to cater for low response when the survey questionnaires were returned. In the Information sheet, participant involvement was explained, and they were assured of their right not to participate. For purposes of anonymity, code names by means of numbers were used in the survey questionnaire. Only the researcher kept records of the names for purposes of tracking the questionnaires to help in identification of participants for the next phase of the study which was the qualitative interview (refer to section 3.3.3.3).

The study participants for the survey questionnaires were Soltai Ltd company employees especially those working in the factory.There were a total of 593 workers working in the cannery section of the company. To obtain a statistically significant representative sample of the factory workers, a "rule of thumb" sample number of the square root of 593 was considered (24). However, 24 participants was considered to be too small and the significance of the results was improved by undertaking a more representative 10% sample of the total factory workers. A total of 59 factory workers were randomly recruited by recruiting every 24th person in the worker's master list provided by the cannery personnel department for this study. The personnel sample included 47 factory workers directly involved in fish cleaning and 9 line leaders, as well as 3 line managers. The 9 line leaders were chosen as they have been assigned responsibility for ensuring that the workers comply with the HACCP food safety system at all times. It was important to establish their knowledge and understanding of the HACCP food safety system in order to compare this with that of the factory workers. To cater for low response, 11 extra factory workers were randomly selected which gave a total of 70 survey questionnaires in all.

The reason for recruiting the line managers to the study was to determine their commitment, knowledge and understanding of the HACCP food safety principles as they are the front liners in ensuring that food safety is a priority in the business. In order to implement an effective HACCP system, managers must be knowledgeable of the HACCP principles and be motivated to implement them. Success can only be achieved through firm commitment of the management and good leadership (Crowther, Herd, & Michels, 1993; Panisello & Quantick, 2001).

Factory workers were vital to the study as they are the key people in the factory who must put into practice what is stipulated in the HACCP food safety system. They must ensure that food safety principles are adhered to at all times, and this can only be achieved with full understanding, continual awareness, effective training, motivation and good management leadership (Setiabuhdi, Theis, & Norback, 1997).

3.3.3.2.2 Framework used for development of the survey questionnaire

A questionnaire based on the 'cognitive and behaviour barrier model to HACCP principles adherence' first developed by Gilling et al. (2001) and adapted by Azanza and Zamora-Luna (2005) was used as a framework to develop the survey questionnaire to determine major barriers to HACCP implementation in food industries (refer to figure 13).

The model as it is, clearly outlines the external and intrinsic factors that could influence knowledge, attitude and behaviour related to HACCP. Since the line of enquiry of this study falls within a similar framework, it makes sense to use a tried and proved survey questionnaire, allowing comparison between this study and that by Azanza and Zamora-Luna (2005). This effectively adds to the validity and reliability of this study. The only addition to the model (refer to figure 31) was the "cultural" aspect of this study. The survey questionnaires were translated into the Solomon Islands "Pijin" English in order for them to understand the questions better. A letter containing the information sheet, explaining the purpose of the study and their involvement (refer to appendix VII), and the survey questionnaire (refer to appendix IX) were sent to the 70 chosen participants. In the Information sheet, participants were assured of their right not to participate.

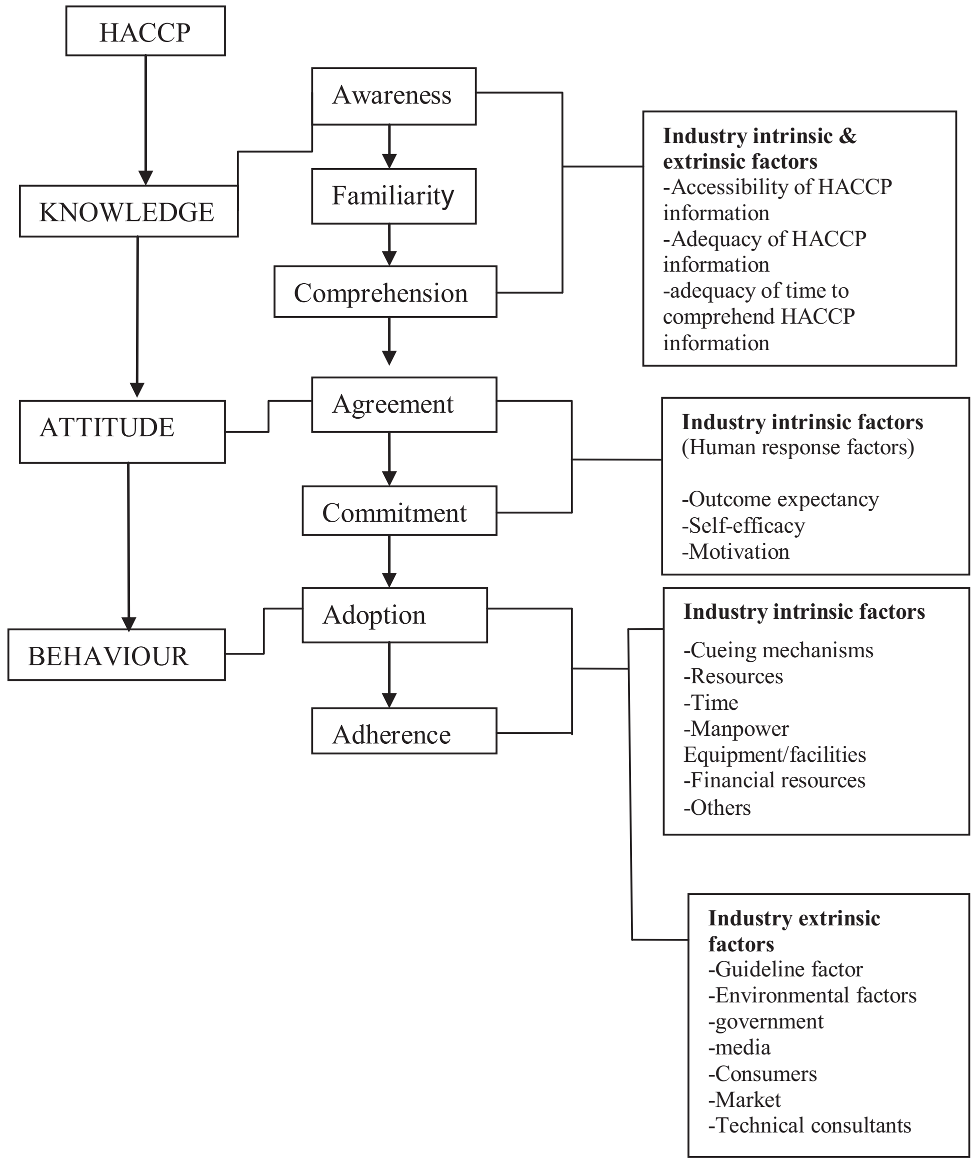


Figure 13: Cognitive and Behaviour Barrier to HACCP Guideline Adherence model. Source: from Azanza & Zamora-Luna (2005).

3.3.3.2.3 Piloting the questionnaire survy

Prior to conducting the actual survey, a pilot study was conducted to determine relevance and clarity of the survey questionnaires. Participants for the pilot study were selected from factory workers, those who were not involved in the actual study. Six factory workers (3 males and 3 females) were involved in the pilot study. This was to obtain fair representative feedback from the sample population who were the key informants to the study. The pilot study was conducted during the first week of the study. The pilot questionnaires were collated and thematically analysed based on their responses to the questions. The process involved identifying common themes derived from their responses as well determining whether the participants really understand and answered the questions asked correctly.Thereafter; a follow up one-on-one conversation was conducted with those involved in the pilot survey, to gather their views on the questionnaire. Based on their feedback, minor amendments such as changing of complicated technical words were made to the survey questionnaires prior to distribution to the study participants.

3.3.3.2.4 Survey questionnaire data analysis (quantitative and qualitative)

SPSS version 17 was used to analyse the data. Prior to data analysis the steps in data processing developed by Kumar (2005), and how to enter and analyse data using SPSS software by Coakes and Steed (2001) was adopted. This involved the following;

- Prior to entering the data into the SPSS data editor, a data cleaning process was conducted. The raw data from each survey questionnaire were scrutinised to check for inconsistencies and incompleteness.The cleaning and editing process involved checking whether or not the questions were answered; if answered, whether the answer is correct or incorrect. It also involved checking how many survey questions were not answered in the survey questionnaire. The process involved examining answers to one question or variable at a time. This is to ensure that none of the questions asked were missed out (Kumar, 2011).
- After the cleaning process, data coding was conducted. Content analysis was conducted to determine the main themes that emerged from the responses given to the survey questions. Based on the content analysis, a variable was defined to be entered in the name column of the SPSS data editor. This followed with assigning numerical codes to each discrete category to be entered under the value labels column in the SPSS data editor. When entering the data into SPSS, all missing values or questions not answered were also taken into consideration. Missing data were kept blank so that the number rules apply. Detailed description of the variable was entered in the labels column of SPSS for more detailed information about the defined variable. Under the measurement level, the defined variables were then categorised under the levels of measurement, as nominal or ordinal or scale. Most of the data were categorised under nominal except for two questions in the survey which were categorised under scale level. Responses to each survey questionnaire were then entered onto SPSS under the variable view spread sheet.
- Data screening. Once all data were entered in the SPSS data editor, the data were checked for any error or incorrectly entered data.
- Descriptive statistics, frequency distributions, measures of central tendency and variability were determined. Once all data entry was checked, then data tabulation and analysis using SPSS was computed to determine frequency distributions and measures

of central tendency and variability (Coakes & Steed, 2001). All the statistical data were entered onto a Microsoft Excel 2007 spreadsheet to draw charts (bar graph, column graph, pie charts, doughnut charts and tables as presented in the results and discussion section below.

3.3.3.2.5 Results

A total of 70 survey questionnaires were distributed to the randomly selected survey participants. Eleven (11) extra survey questionnaires were issued in addition to the original 59 randomly selected factory workers. This was to cater for any low response when the survey questionnaires were returned.A total of (n=51) factory workers (participants) within the cannery section of the company participated in the survey questionnaire. This is equivalent to 86% response rate, which indicates a good response to the survey questionnaire. Participants' included those working in the production line and those working outside, packing and labelling. Of the total participants who participated in the survey questionnaire, 67% were females and 33% were males.

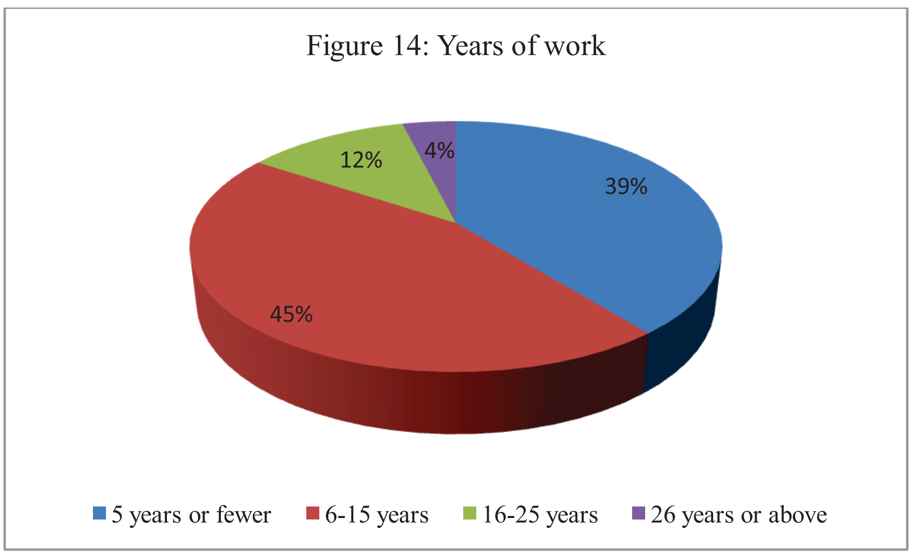


Figure 14: Shows the distribution (%) of participants' years of work in the factory at Soltai Ltd. 45% range from 6-16 years of work, 39% 5 years or fewer, 12% between 16-25 years of work and 4% have worked for 26 years or above. A high percentage (45%) of workers had worked in the factory between 6-15 years and also a high percentage (39%) who have worked in the factory for 5 years or less. The results suggest that there is high turnover of workers in the factory, though there is a significant core of experienced workers (veterans) who, if properly trained, should be regarded as an asset to be used in maintaining consistency of hygiene practises with newer staff. The high percentage (39%) who worked 5 years or less could be due to recent recruitment of casuals to work as fish cleaners as a result of increase of production tonnage in the factory.

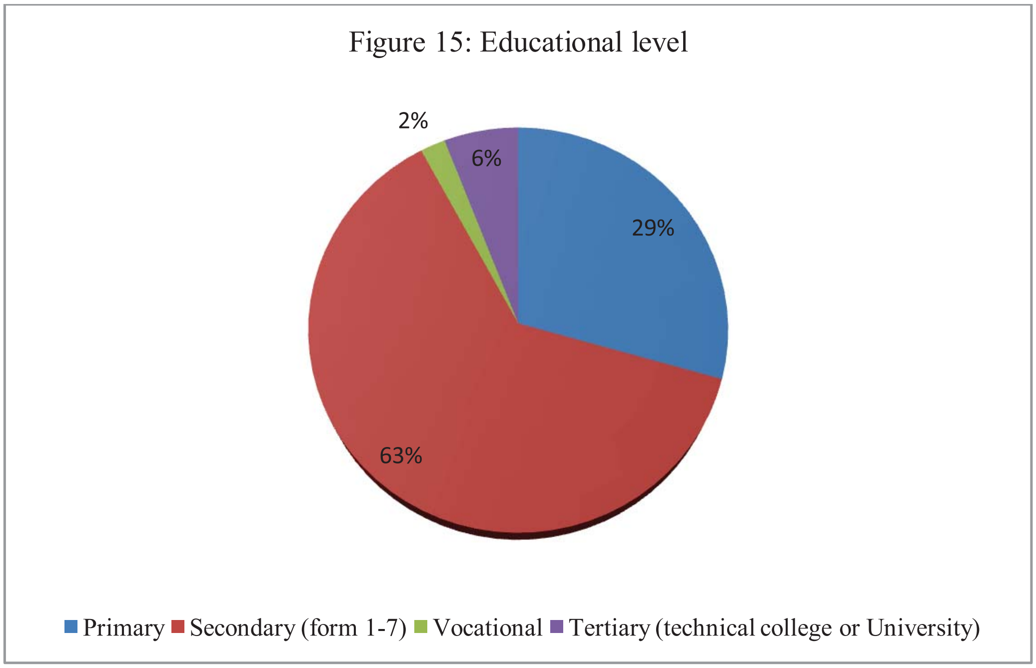


Figure 15: Shows the highest educational level reached by the participants.63% of the respondents attended secondary education, 29% attended primary level, 6% attended tertiary (technical college or university) level and 2% attended vocational level and 0.84% did not attend any formal school.

Table 7: Familiarity with terms food hazard & food risk

Statement	%
Understand the term food hazard	
Correct – example, food that might be a biological, chemical or physical agent is reasonably or likely to cause illness or injury in the absence of its control	35.3
Broad/partly correct - example, anything that should not be in the food for human consumption	29.4
Incorrect - example, very poor handling can cause iron, metal to be present in the fish product	25.5
No response	9.8
Understand the term food risk	
Correct – example, that a major public health problem that is by eating food containing a significant amount of harmful (pathogenic) or toxic material not safe for human consumption	35.3
Broad/partly correct - example, food is not prepared in a manner fit for human consumption and could be a risk to human lives when taken	21.6
Incorrect – example, proper handling of food	37.3
No response	5.9

Table 8: Reference definitions

Term	Definition
Food hazard	A biological, chemical or physical agent in or condition of, food with the potential to cause an adverse health effects (CAC, 2003).
Food risk	A function of the probability of an adverse health effect and the severity of the effect consequential to a hazard(s) (Jouve, Stringer, & Baird-Parker, 1998).

Table 7 portrays the participants' responses on their understanding of the terms "food hazard" (what might happen) and "food risk" (how likely it is to happen and how badly it will affect you if it does). 35.6% define the term food hazard correctly, 29.4% defined the term "food hazard" in a broad sense, 25.5% incorrectly defined the term and 9.8% did not respond to the question. Likewise, for the term "food risk", 35.3% define the term correctly, 21.6 define the term in a broad sense/partly correct, 37.3% incorrectly define the term and 5.9% did not respond to the question. Based on the above table, it can be concluded that 35.3% of the participants do not really understand the term food hazard and 25.5% who defined the term in broad sense could be that they are not really certain about what food hazard means. Likewise the majority (43.3%) of the participants do not really understand what food risks are.

Figure 16: Familiar with the term HACCP

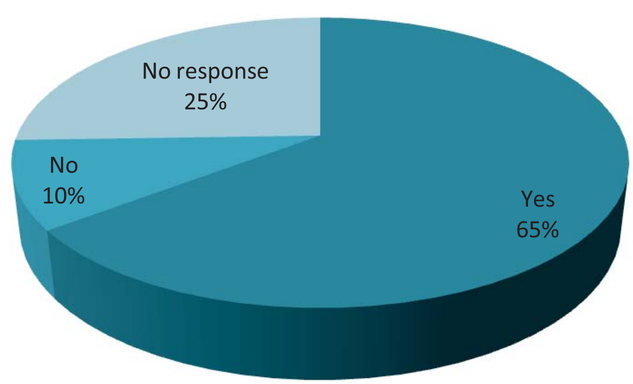


Figure 16: Shows the participants response when they were asked whether or not they are familiar with the term HACCP. The majority (65%) participants responded yes, 25% did not respond to the question and 10% were not familiar with the term HACCP. The above result was consistent with the following questions, and though a high percentage of the factory workers heard and knew about HACCP recently (refer to figure 19), a high percentage of participants were not familiar with the 7 principles of HACCP (refer to figure 17) and the majority (56.8%) of the participants did not attend any training on HACCP (refer to figure 18).

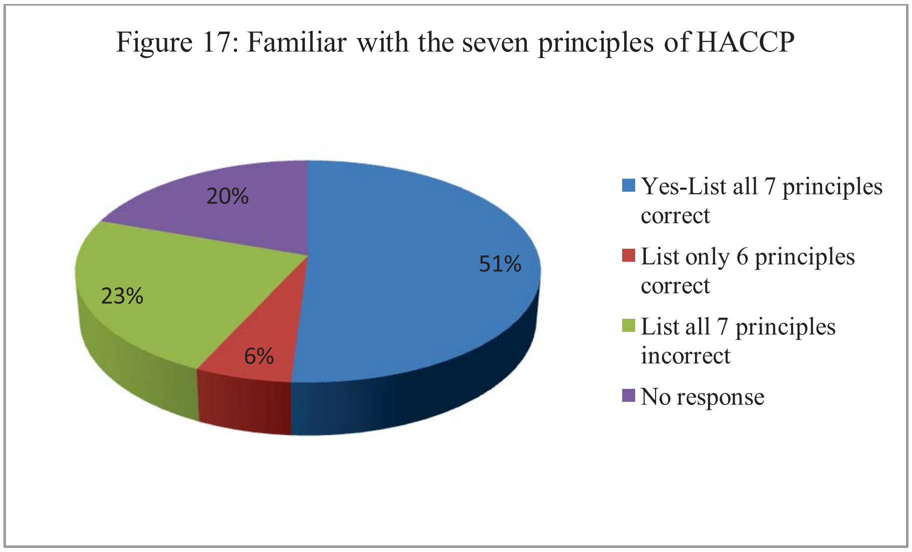


Figure 17: Shows the participants understanding of the seven principles of HACCP. 51% listed all the 7 principles correctly, 23% did not respond to the question, 20% listed all 7 HACCP principles incorrectly, and 6% listed only 6 HACCP principles correctly. Based on the above pie chart, although the majority (51%) are familiar with the 7 principles of HACCP, there is also a big proportion (49%), of the participants who are not really familiar with the 7 HACCP principles. This could be due to a high percentage of workers not attending HACCP trainings (refer to figure 18) prior to recruitment, or could be that there is a lack of information on HACCP principles available in the factory (refer to figure 20). The other reason could be due to lack of in house training awareness programmes offered for the workers, therefore, they are not aware of the HACCP principles.

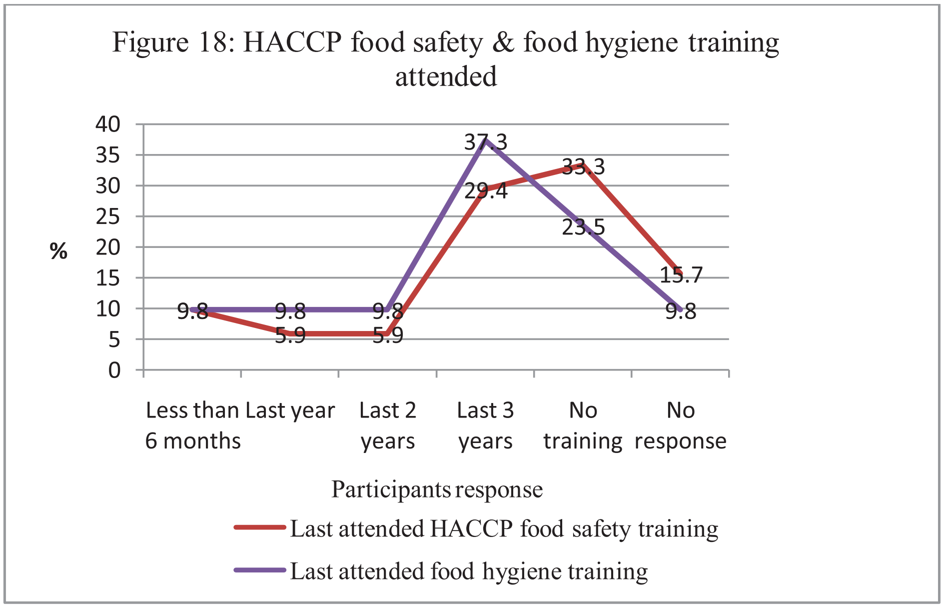


Figure 18: Shows participants distribution (%) as to when they last attended the HACCP food safety training or food hygiene training. 9.8 % responded that they attended the HACCP training less than 6 months, 5.9% indicated that they attended the HACCP training the previous year and 2 years before. 29.4% responded that they attended HACCP training 3 years before, 33.3% indicated that they did not attend any training on the HACCP principles and 15.7% did not respond to the question.The trend was similar for those attending food hygiene training, with 9.8% indicated that they attended food hygiene training between 6 months and 2 years prior, 37.3% responded that they attended food hygiene training in the last 3 years, 23.5% indicated that they have not having attended any training on food hygiene at all, and 9.8% did not respond to the question.

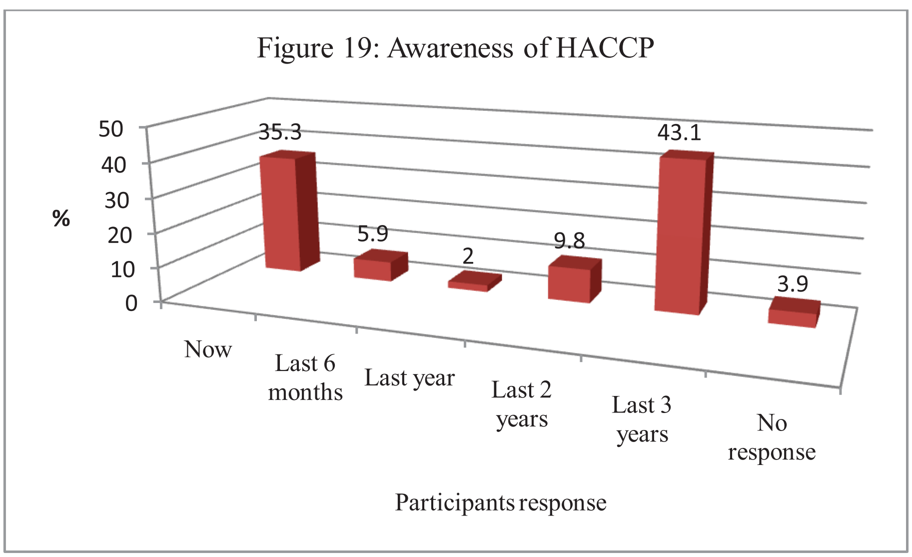


Figure 19: Shows the participants response when they were asked when they first heard or read about HACCP food safety system. Forty three point one percent (43.1%) indicated that they first heard or read about HACCP last 3 years ago, 35.3% just heard about HACCP now, 9.8% 2 years ago; 5.9% heard about HACCP the last 6 months and 2% heard about HACCP last year. 3.9% did not respond to the question.

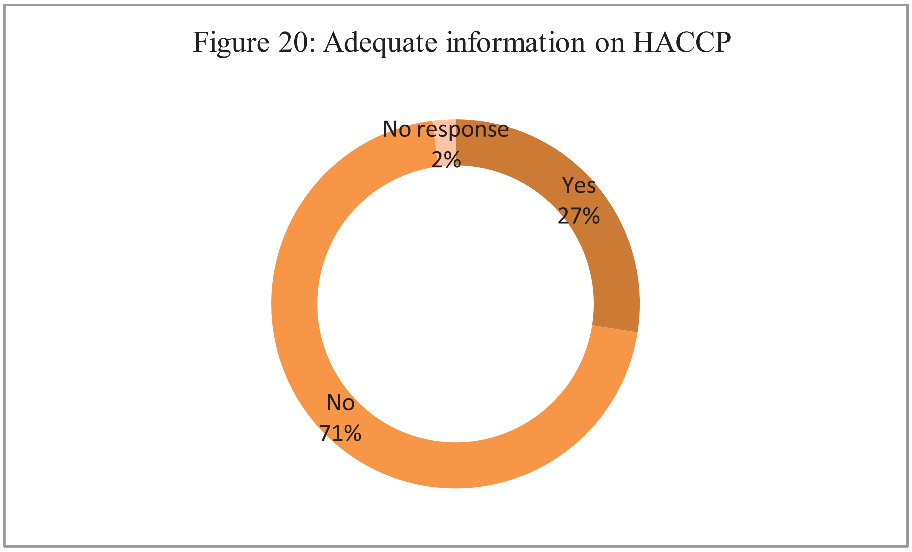


Figure 20: Shows the participants response when they were asked whether there is adequate information on HACCP in the factory.71% chose "no", there is inadequate information provided in the factory, 27% responded "yes", there is adequate HACCP information provided and 2% did not respond to the question.

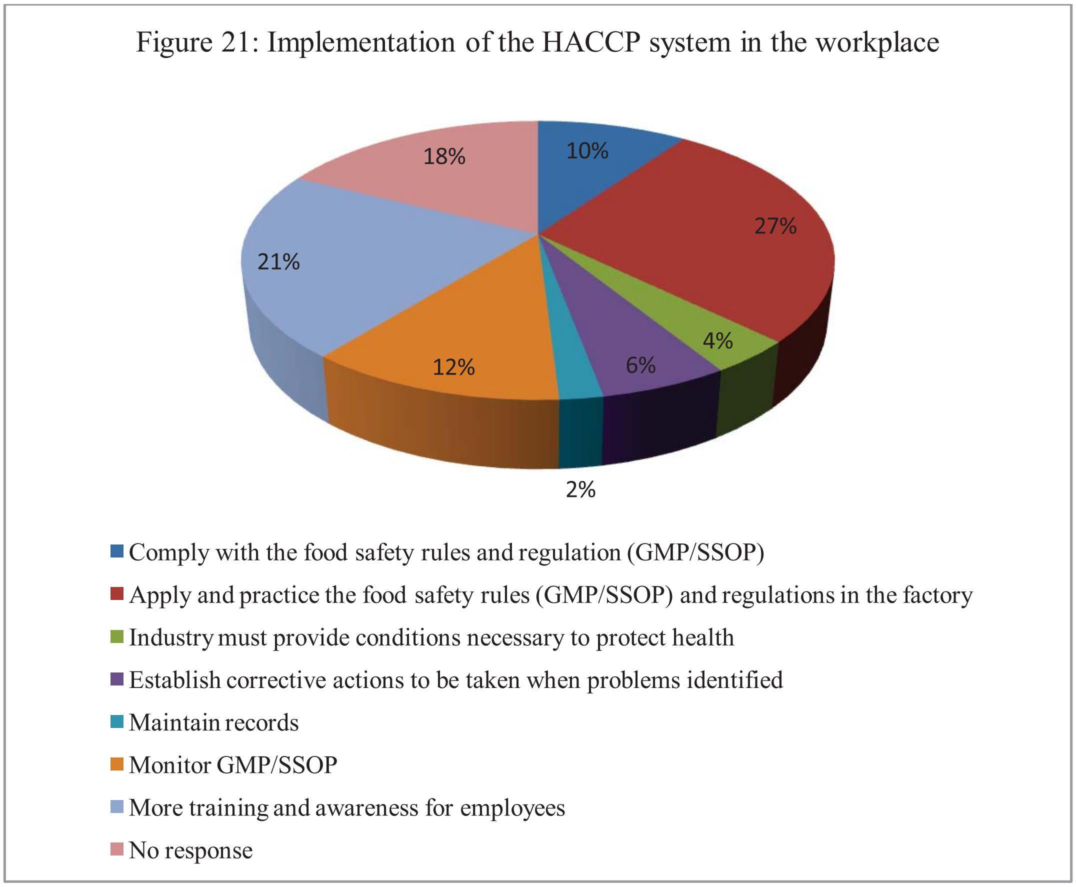


Figure 21: Shows the results of participants' comprehension and application of the HACCP system in the factory.27% responded that they apply and practice the food safety rules (GMP/SSOP) and regulations in the factory. 21% indicated, that more training and awareness should be conducted for the employees, 18% did not respond to the question, 12% indicated monitor GMP/SSOP and 10% thought that they comply with food safety rule and regulations. 6% responded by establishing corrective actions to be taken when problems identified, 4% thought that the company must provide conditions necessary to protect health and 2% indicated that, records should be properly maintained.

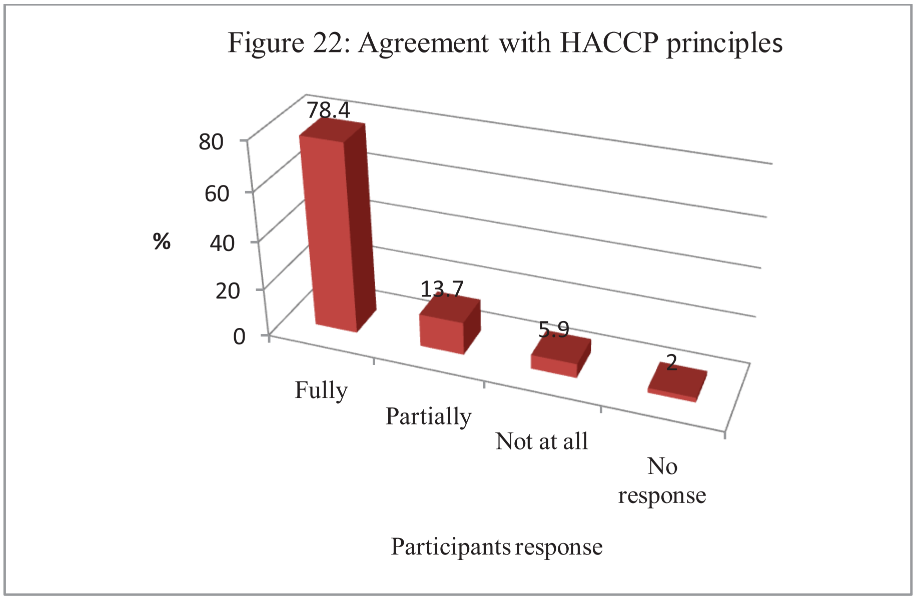


Figure 22: Shows the results of participants' agreement with HACCP principles.78.4% fully agree with implementation of the HACCP system, 13.7% partially agree with implementation of the HACCP system, 5.9% did not agree and 2% did not respond to the question.

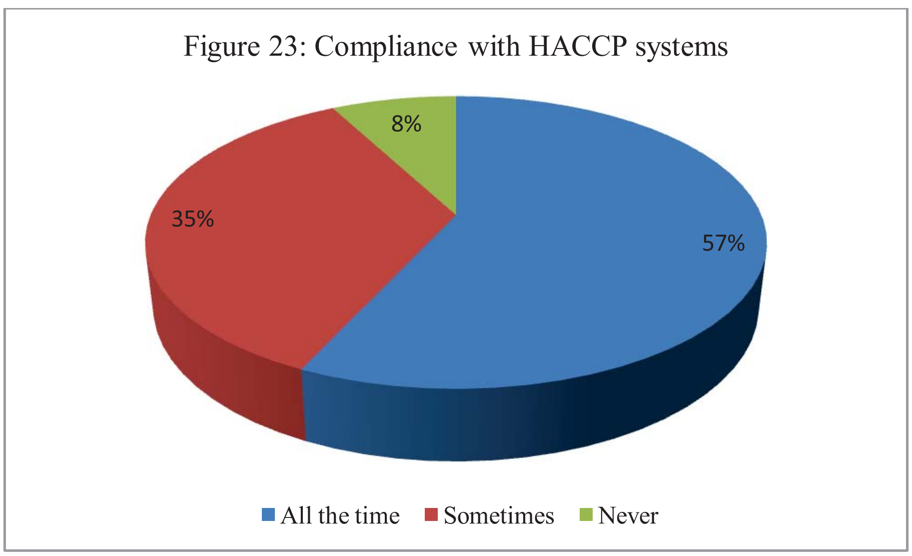


Figure 23: Depicts the participants' compliance with the HACCP system in the factory.57% stated that, they comply with the HACCP principles all the time, 35% sometimes and 8% never. A high proportion (43%) ("sometimes" and "never") are not adhering to the HACCP system in the factory. This should be an indicator to the company that, although the majority (57%) of the participants who indicated that they complied with the HACCP system, a high percentage (43%) clearly do not comply with the HACCP system all of the time.

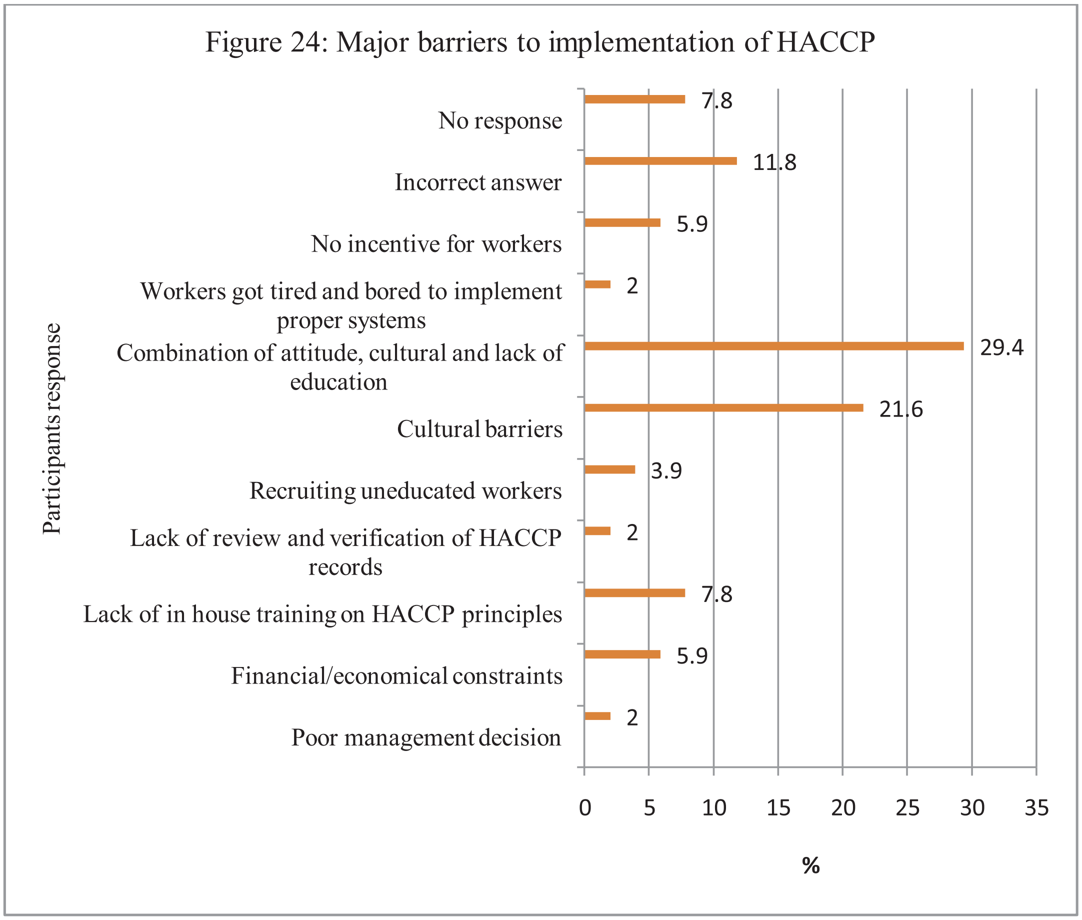


Figure 24: Shows the participants' responses to the question, what were the major barriers to implementation of the HACCP food safety management system at Soltai Ltd. 29.4% responded that it was due to a combination of attitude, cultural and lack of education, 21.6% indicated that it was due to cultural barriers and 11.8% did not answer the question correctly. 7.8% thought, that it was due to lack of in house training on HACCP principles, 5.9% responded that it could be due to financial constraint and no incentive for workers and 3.9% thought that it was due to recruiting uneducated workers.2% responded that it was due to poor management decisions, and 2% indicated that workers got tired and bored to implement proper system. Another 2% thought that it is due to lack of review and verification of HACCP records and 7.8% did not respond to the question.

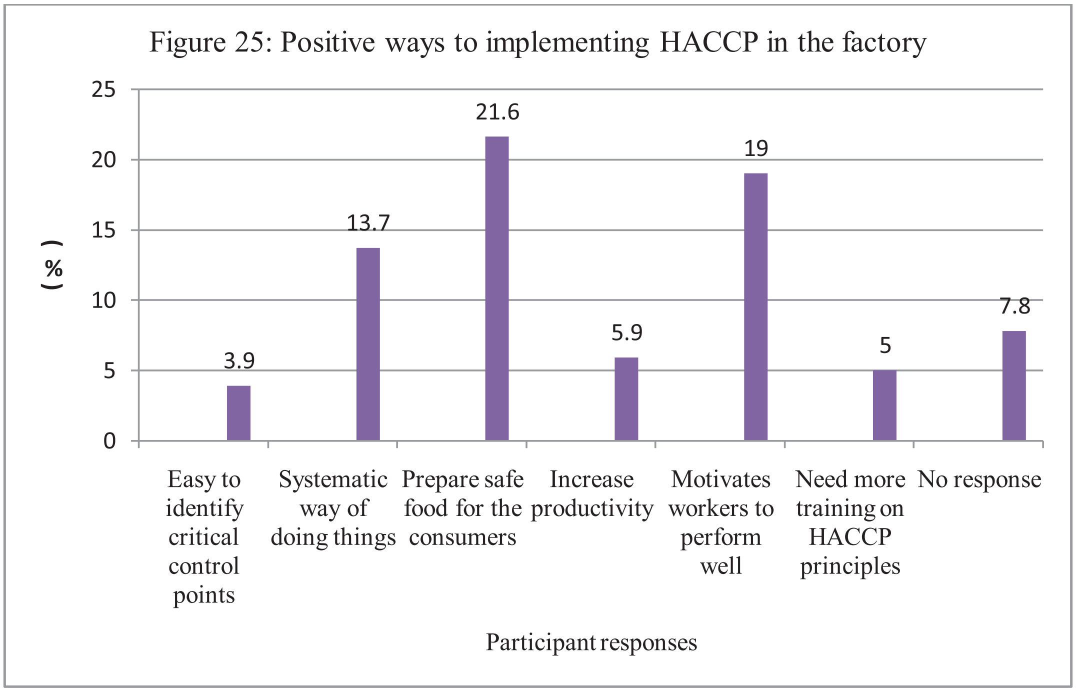


Figure 25: Shows the participants' response when they were asked what major positive benefits the company can derive from implementing the HACCP food safety system? 21.6% answered, prepare safe food for the consumers, 19% considered it motivates workers to perform well and 13.7% thought that it enhances systematic way of doing things in the factory. 7.8% did not respond to the question, 5.9%, thought it will increase productivity, 5% implied they need more training on HACCP principles and 3.9% thought that it is easy to identify critical control points.

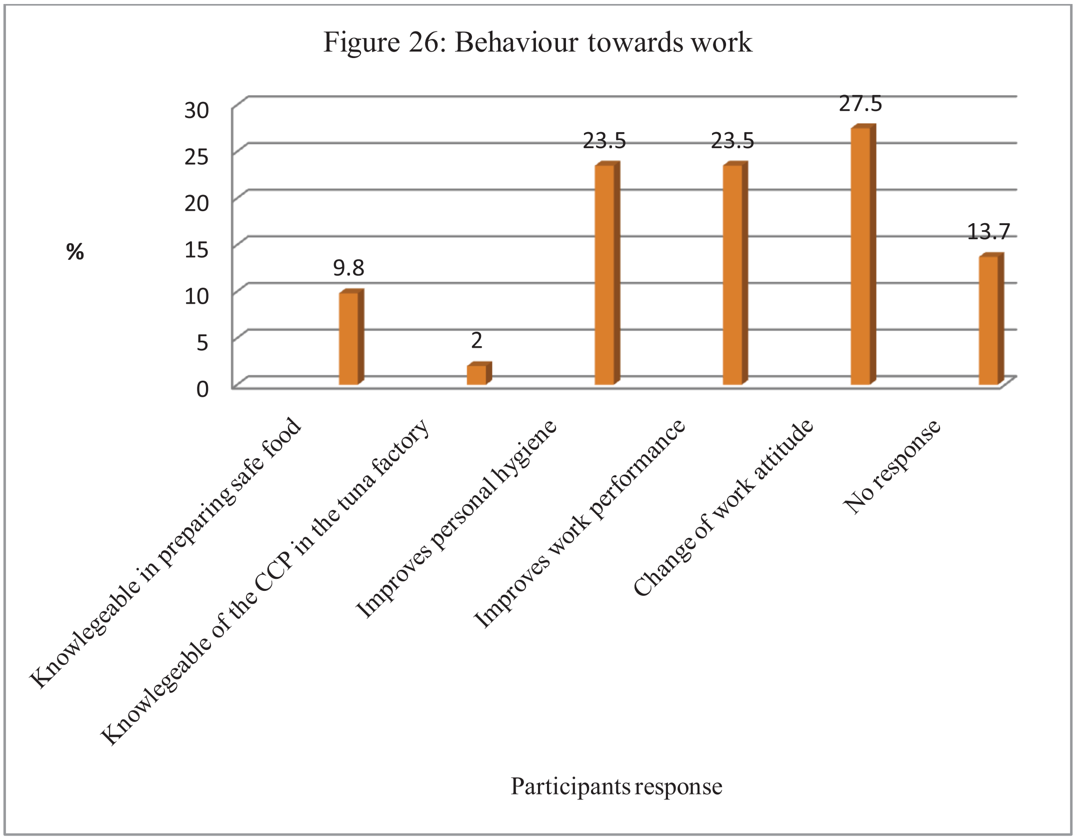


Figure 26: Depicts the participants' understanding and behaviour towards work performance in the factory. 27.5% responded that their understanding on HACCP principles changes their attitude of work, 23.5 % thought that it improves their work performance and improve their personal hygiene, 13.7 did not respond to the question, 9.8 % responded that they are knowledgeable in preparing safe food and 2% responded that, they are more knowledgeable of the critical control points in the tuna factory.

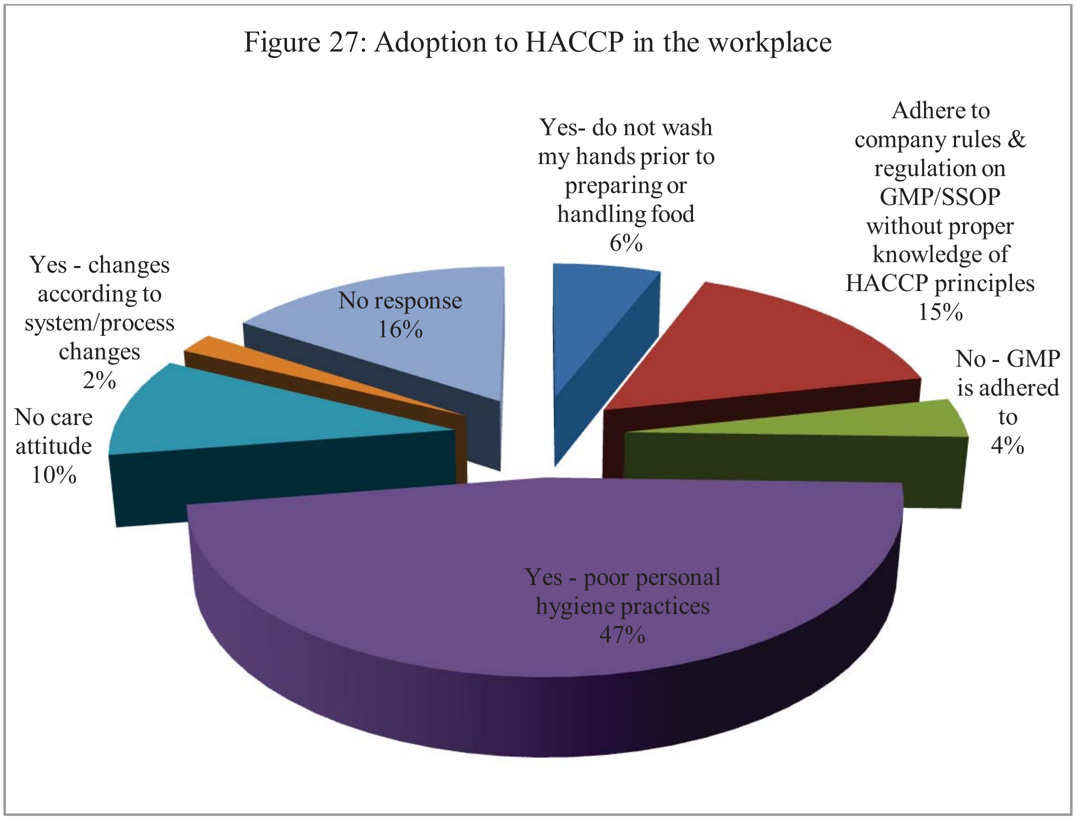


Figure 27: Shows the participants' responses when asked the question, before you heard about HACCP guidelines, did you do anything differently in the workplace. 47% responded yes – poor personal hygiene practices, 15% thought that they adhere to company rules & regulations on GMP/SSOP without proper knowledge of the HACCP principles and 10% indicated a no care attitude. 6% responded yes, they do not wash their hands prior to preparing or handling food, 4% chose no, they do adhere to GMP's, 2% responded, yes- they comply according to system/process changes and 16% did not respond to the question.

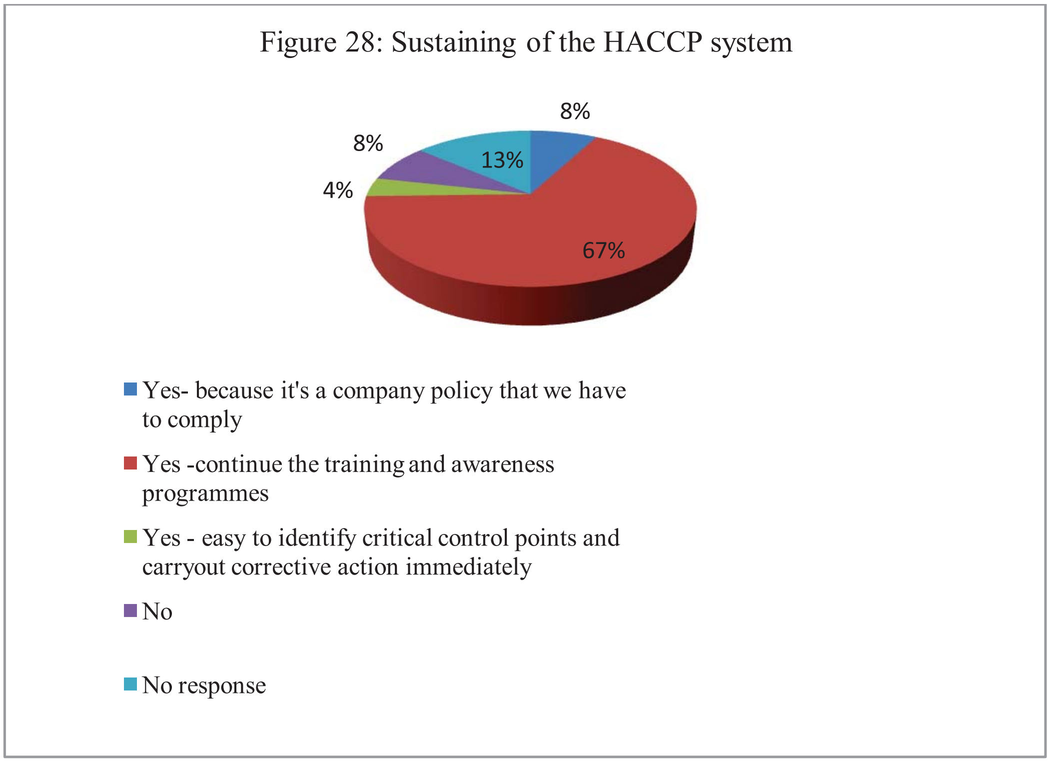


Figure 28: Shows the participants response when they were asked, whether it is easy to sustain the implementation of the HACCP guidelines in their line of work. 67% indicated, yes- continue the training and awareness programmes, 13% did not respond to the question and 8% chose no. 8% responded, yes- because it's a company policy that we have to comply with and 4% chose, yes- easy to identify critical control points and carryout corrective action immediately.

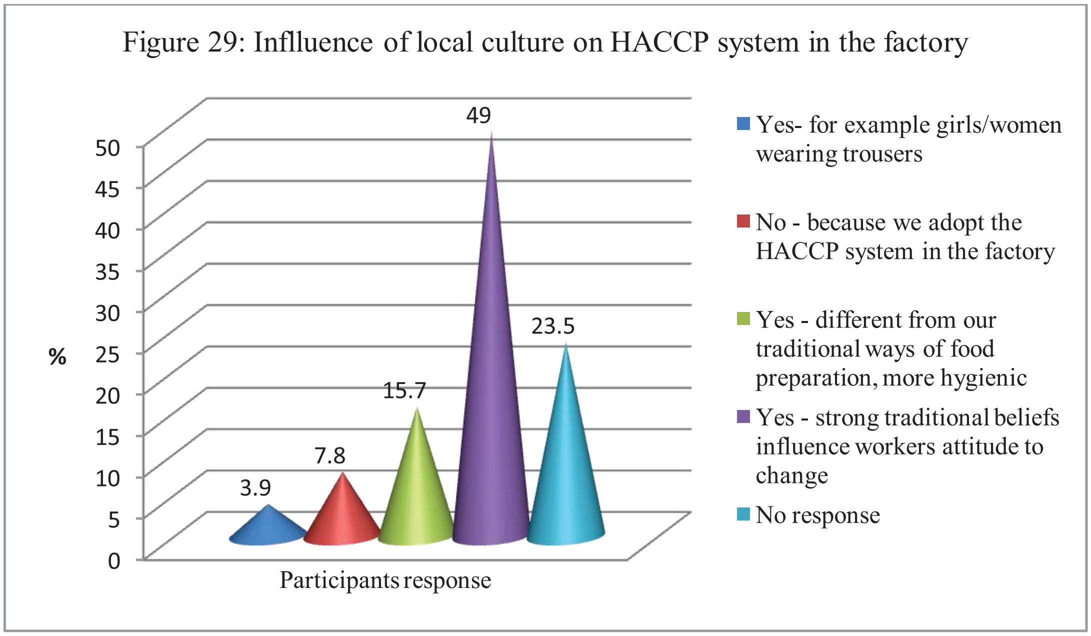


Figure 29: Shows the participants' response when asked whether the local culture does have a lot of influence on the implementation of HACCP food safety system in the factory. 49% indicated, yes- strong traditional beliefs influence workers attitude to change, 23.5% did not respond to the question. 15.7% responded, yes- different from our traditional ways of food preparation, more hygienic, 7.8% chose, no- because we adopt the HACCP system in the factory and 3.9% responded, yes- for example girls/women wearing trousers.

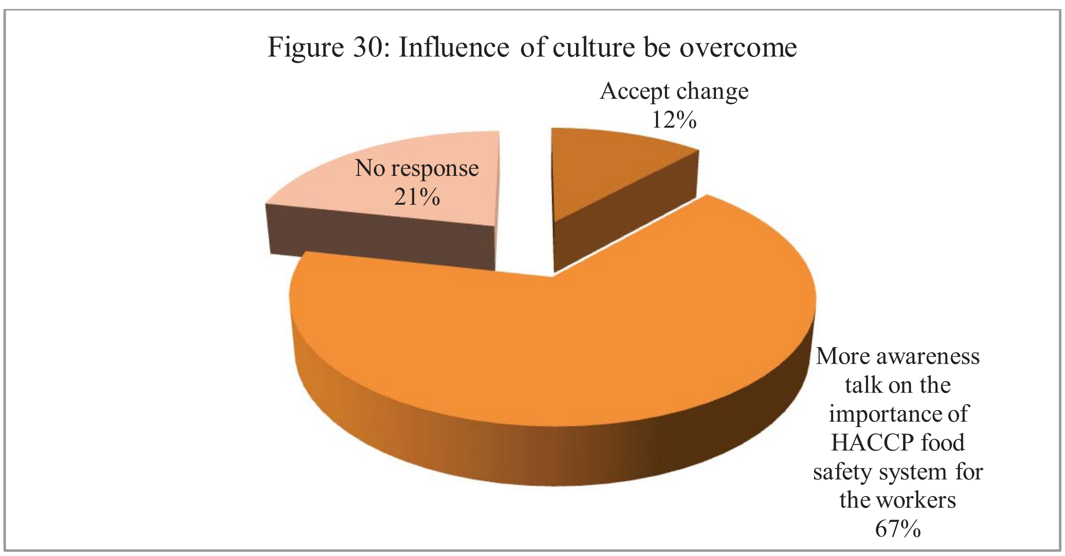


Figure 30: Shows the participants' response when asked how the influence of the local culture can be overcome. 67% responded that more awareness talk on the importance of HACCP food safety system should be conducted for the workers. 12% chose, accept change and 21% did not respond to the question.

Table 9: Attitude/perception checklist

Statements	N - valid	Missing	Med	Range	Min	Max
The company is responsible for delivering safe fish/fish products to its consumers	47	4	5.00	4	1	5
Top managers are fully committed to ensure the safety of fish/fish products	45	6	4.00	4	1	5
Staff training on food safety is important	43	8	5.00	4	1	5
Unsafe food handling practices can increase the risk of our fish/fish products	46	5	5.00	4	1	5
The company is able to respond to and satisfy customer and market requirements for food safety	46	5	4.00	2	3	5
Operators are motivated to ensure the safety of the fish/fish products	44	7	4.00	2	3	5
HACCP implementation must be a mandatory requirement for the fish industry in the Solomon Islands	46	5	5.00	3	2	5
I have access to all information required about food safety management	46	5	4.00	4	1	5
Inspections and audits of the food safety management system provide opportunities for improvement	46	5	5.00	4	1	5
I am well informed about current laws/regulations governing food safety	46	5	4.00	4	1	5
The company has qualified personnel to effectively manage the safety of its fish/fish products	44	7	4.00	4	1	5
There is a need for a culture change in staff to better manage food safety	45	6	4.00	3	2	5
The company has received pressure from stakeholders to implement a food safety management system	44	7	4.00	4	1	5
I am well informed about food safety and how to manage it	45	6	4.00	4	1	5
The management of food safety is a burden to the company	45	6	4.00	4	1	5
There is close collaboration between the fish industry and the government to promote food safety management programmes	44	7	4.00	4	1	5
The company delays to solve food safety incidents	42	9	2.00	4	1	5
A food safety management system is difficult to apply in a company of our size	44	7	2.00	4	1	5
There is risk that someone can contract food poisoning from our fish/fish products	46	5	4.00	4	1	5
There is no real incentive for having a HACCP/food safety management system	45	6	2.00	4	1	5
Food safety is not really a business priority	45	6	2.00	4	1	5

Table 9 shows the median score of the degree of agreement or disagreement of the participants' with the proposed attitude/perception statements. The five statements with highest score (5.00) were "the company is responsible for delivering safe fish/fish products to its consumers", staff training on food safety is important", "unsafe food handling practices can increase the risk of our fish/fish products", "HACCP implementation must be a mandatory requirement for the fish industry in the Solomon Islands", and "inspections and audits of the food safety management system provide opportunities for improvement". The statements with the lowest median score (2.00) were "the company delays to solve food safety incidents", "a food safety management system is difficult to apply in a company of our size", "there is no real incentive for having a HACCP/food safety management systems" and "food safety is not really a business priority".

3.3.3.2.6 Discussion

This study involved assessment of the participants' awareness, familiarity and comprehension of the HACCP principles. For this assessment, the industry intrinsic and extrinsic factors were considered.These included evaluation of the factory workers accessibility to HACCP information, adequacy of HACCP information and the adequacy of time to comprehend HACCP information.

The majority of the factory supervisors and Quality Control staff personnel's had attended HACCP and food safety training sessions (F.Fekau, personal communication, October 7, 2010). However, the problem lies in the fact that, the majority of the fish cleaners had not undergone any intensive training on HACCP and food hygiene, apart from the 30-60 minutes awareness talk on personal hygiene conducted during the induction session prior to work. One could not expect anyone, who has not been exposed to such modern way of food preparation, to quickly grasp and understand the new concepts such as the HACCP principles in one very brief session. Although it can be assumed that the majority of the supervisors and QC staff had undergone intensive training on HACCP principles and food safety, as monitors of the SSOP/GMP in the factory, the lack of training of the fish cleaners who handled the fish products on daily basis is a clear impediment to effective implementation of the company HACCP food safety system.
This is supported by Hielm, Tuominen, Aarnisalo, Raasaka and Maijala (2006), in their study on determining the attitudes towards own checking and HACCP plans among Finnish industry that, where they report that the focus of HACCP training has been mainly on managers and supervisors with very little emphasis placed on the company labourers' attitude. The HACCP food safety system can only work if HACCP principles are well understood by all employees and the whole personnel are committed to implement it (Panisello & Quantick, 2001). Furthermore, risk management strategies can only work if they are internalised by all company employees (Mortimore, 2001). There is often a significant lack of well educated and or highly trained personnel within the workforces of food companies within developing countries, and this can present problems, particularly in hazard identification and assessment activities (Jirathana, 1998).

The supervisors and QC staff may have done a great job in ensuring that SSOP/GMP's are enforced and adhered to at all times in the factory. But, if the majority of the workers (fish cleaners) are not well versed with the HACCP principles including the pre-requisite programmes (SSOP/GMP), then it does not serve its purpose. There is possible risk of cross contamination by the food handlers due to lack of knowledge and understanding of basic good hygiene practices.This was evident in the study at Soltai Ltd.Though the majority of the workers were familiar with the term HACCP (refer to figure 16), a high percentage do not fully understand the 7 principles of HACCP (refer to figure 17).This could be the reason why the majority of the participants could not really differentiate between food hazards and food risks (refer to table 7). This could also have a strong association with high percentage of the participants not attending training on HACCP and food hygiene in general (refer to figure 18).This emphasizes the fact that there is inadequate information on HACCP available in the factory (refer to figure 20). Based on my observation in the factory, there are adequate SSOP/GMP sign boards on the walls in and outside the factory written both in English and “Pijin” English for the workers to adhere to. However, the documented HACCP materials are not being made available to the workers for reading so that they fully understand what HACCP is all about.This should include the translated version of the HACCP (SSOP/GMP) information in the Solomon Islands “Pijin” English.

It could be argued by some that, factory workers do not really need to understand and differentiate between food hazards and food risks. However, this view could defeat the purpose of maintaining a stringent HACCP food safety system in the factory. HACCP food safety system is meant to be implemented to safe guard consumer health. Therefore, factory workers who are handling the tuna products daily should be the ones taught how to differentiate between food hazards and food risks on the food processing chain. Simple ‘robotic’ training will not adequately prepare personnel for changing circumstances. It is only through proper in depth training, and thereby having a good understanding of what the food hazards and risks are that they will take necessary precautions to ensure that fish products are safe for human consumption. Neglecting the training needs of this group of workers would mean that there is high risk of cross contamination of fish products due to ignorance. Staff are more likely to slip into ‘old habits’ borne of traditional ways of preparing foods.

Based on figure 18, 66.7% indicated that they attended training within the last 3 years, 56.8% did not attend any training on HACCP and food hygiene, 35.3% attended training less than 6 months or a year ago.The evidence suggests that the majority (82.4%) of the company employees last attended HACCP and food hygiene trainings during the past 2- 3 years. This is a significant matter which the company must address with urgency. Without frequent refresher training and encouragement or motivation, employees tend to forget or ignore HACCP principles and the importance of their role in maintaining SSOP/GMP’s in the factory. Given the low educational background of most of the workers in the factory (refer to figure 15), training will have a significant impact on the effective implementation of the HACCP food safety system in the factory.Attendance at annual food safety training workshops should be compulsory for continued employment, and given number one priority in order for the workers to refresh their understanding and knowledge of HACCP principles. This could be the reason why the majority of the workers (35.3%) indicated that they only became aware of HACCP recently, while 52.3% had heard of the HACCP principles within the last 2-3 years ago (refer to figure 19).

Similarly, the adequacy of the time to fully comprehend the information on HACCP principles, including SSOP/GMP, is a significant factor given that about 29 % of the factory workers only reached primary school level as their highest form of education (refer to figure 15).

Although high percentage (63%) of the participants reached secondary level, it is obvious in the context of the Solomon Islands that people will still find reading and writing in English difficult. Reading and understanding the technical information on HACCP in English could be a major barrier. The time taken (30-60 minutes) for the awareness talk to introduce HACCP information including the SSOP/GMP's to new workers is inadequate for them to comprehend HACCP principles.Similar studies conducted by Azanza and Zamora-Luna (2005) in the Philippines using the same model revealed that, even respondents who graduated from tertiary education in food technology and food science related fields who had some level of HACCP knowledge still perceived that HACCP information from available sources was limited.The study went on to emphasize that, even if the information was made available, HACCP team members still felt that they were not generally given adequate time to fully comprehend.

In the case of Soltai Ltd where the majority of the workers are primary school leavers, this would account for why the majority of the participants were not aware of and knowledgeable about the HACCP principles. Even if they were cogent of HACCP principles, including the SSOP/GMP's (refer to figure 16, 17 & 19), to fully comprehend and understand the HACCP principles and the pre-requisite programmes is the problem at Soltai Ltd. Furthermore, in the factory, regardless of putting up personal hygiene sign boards in the wash hand station on how to wash their hands properly, it was observed that the workers seem not to pay much attention to or follow the instructions thoroughly. Because of low educational background, it is possible they do not really understand the sign boards, or they have developed a "habit" of not washing their hands properly in their homes prior to coming into the factory.

Furthermore, although Soltai Ltd has a well documented HACCP food safety system in place, it appears that the workers do not really understand what HACCP is all about or what their role is in effecting it. Even though the supervisors and managers are aware of the HACCP, they have not effectively passed this on to those in the best position to ensure they are effective, such as the fish cleaners. This suggests there is not enough information on HACCP available within the factory (refer to figure 20).

A combination of attitude, culture and lack of education were the major barriers to effective implementation of the HACCP at Soltai Ltd (refer to figure 24). Knowing well that the majority of the workers were recruited direct from their villages to the factory, it should be assumed that there will be difficulty changing attitudes and behaviour overnight. Cultural beliefs and norms in many cases are in conflict with the organisational culture. For example, it was observed in the factory, that workers, although provided with brushes to clean their hands properly, were not using them.In some instances, detergent to wash their hands properly was not provided, or existing containers not refilled at the wash hand stations, leaving the workers with no option but to just rinse their hands with water and enter the production room and handle tuna products. It was also noted in the afternoons when they were feeling tired and dozy, that the workers sing songs, a practice and behaviour which are not accepted in food industries. It was also observed that workers were seen smoking while wearing their work uniforms.These are poor personal hygiene practices, behaviours and attitudes which are strongly influenced by the local culture. It is difficult to change the factory workers' attitude and behaviour quickly when they have been brought up with a different approach for most of their life.This has been one of the challenges and barriers to the implementation of the HACCP food safety system at Soltai Ltd. The high percentage of non compliance (refer to figure 23), no doubt has close association with low literacy rate (refer to figure 15) and the influence of cultural behaviours and attitudes (refer to figure 24).

In the context of the Solomon Islands, culture does have a great influence on the workers' attitude and behaviour towards implementing the HACCP food safety system in the factory (refer to figure 31). Therefore, there is a need to translate some of the HACCP information into the Solomon Islands "Pijin" English (*lingua franca*, which is spoken and understood by all) in order for the workers to comprehend the HACCP principles well. This is supported by the findings of a study conducted by Jirathana, (1998), on the implementation of HACCP in Thailand, which identified a number of constraints, including availability of HACCP documents in the native language. In developing countries, the supply of native language HACCP documentation is likely to be very limited.Consequently; there is a heavy reliance upon foreign language (predominantly English) documentation and English speaking employees.

Attitude and behaviour was reflected in the participants' agreement and commitment. Attitude and behaviour was determined by their adoption and compliance (adherence to) with the implementation of the HACCP food safety system in the factory.The study revealed that the majority of the participants fully agreed with the implementation of the HACCP principles including the pre-requisite programs in the factory (refer to figure 22). Based on data in figure 26, it is evident that workers do value the importance of implementing HACCP food safety system in the factory. The majority (62.8%) responded positively towards implementing HACCP food safety system in the factory. Their understanding of implementing the HACCP principles had impacted on their behaviour towards food safety and personal hygiene in the factory. This indicates that, though the majority do not attend trainings on HACCP principles or food hygiene (refer to figure 18) or there is inadequate information available on HACCP principles in the factory (refer to figure 20), their direct involvement in implementing the SSOP/GMP's in the factory has changed their behaviour towards implementing HACCP principles in the factory. There was strong disagreement with the following statements, "the company delays to solve food safety incidents", "a food safety management system is difficult to apply in a company of our size", "there is no real incentive for having a HACCP/food safety management systems" and "food safety is not really a business priority", and this highlights their positive attitude and perception towards HACCP principles in the factory (refer to table 9).

Based on the checklist (refer to table 9), it can be concluded that the majority of the factory workers at Soltai Ltd do have a positive attitude and perception about the implementation of the HACCP food safety system in the factory.They value the importance of implementing a stringent HACCP food safety system and this is evident in their strong agreement with the following statements, that "the company is responsible for delivering safe fish/fish products to its consumers", "staff training on food safety is important", "unsafe food handling practices can increase the risk of our fish/fish products", "HACCP implementation must be a mandatory requirement for the fish industry in the Solomon Islands", and "inspections and audits of the food safety management system provide opportunities for improvement".

Attitude and behaviour always go hand in hand as they are inter-related.They influence each other in that they may affect the quality of the food by workers' adherence to regulations, and general performance in the factory. Attitude and behaviour are also strongly influenced by industries intrinsic (human response factors and resources) and extrinsic factors or dispositions. For example, it stands out very clearly in the study that those participants' who did not fully agree with the HACCP principles are probably the ones who were not complying and not committed or adhering to implementation of the company SSOP/GMPs (refer to figure 22 & 23). This is likely due to lack of motivation or to the influence of other extrinsic factors such as culture. The intrinsic factors in the industry such as incentives provided, or outcome expectancy in terms of job remuneration could also contribute a lot to the workers attitude and behaviour, which in turn would affect the quality of food manufactured.This could be greatly influenced by the quality management system adopted, and the technology and style of management system in place in the food industry (Luning & Marcelis, 2006, 2007).

Similar studies conducted by Luning and Marcelis (2009) to determine systematic assessment of core assurance activities in a company specific food safety management system, revealed that personnel behaviour toward quality issues, such as safety, depends on disposition and ability of the employee to behave in a certain direction.Disposition depends on aspects like personal quality standard, quality knowledge, observed standards of colleagues and boss, and observed opportunities. Ability depends on issues like competencies, facilities and means, availability of time, and support of colleagues, supervisor and company. This is further supported by Buccheri, et al. (2010), in a study to determine knowledge, attitudes and self reported practices of food service staff in nursing homes and long care facilities, who conclude that, education level, length of services in the job and attending courses on food hygiene influenced the knowledge, attitudes and practices of food service staff.

3.3.3.3 Phase four – qualitative research

3.3.3.3.1 Sample size and selection of participants

For the qualitative research, one on one exploratory *(talanoa)* cultural interviews were conducted with selected factory workers and managers in the factory. This was to explore their views on local culture, and also explore possible influences cultural practices may have on the implementation of the HACCP food safety system in place at Soltai Ltd. Participants for the qualitative one on one exploratory (*talanoa*) interviews were sourced from the same participants who were involved in the survey questionnaire.Participants were selected based on their responses to the questions asked about the cultural influence to the implementation of the HACCP system in the factory. Participants were selected for diversity of responses taking into consideration their work experiences. Participants were a mixture of male and female. In terms of hierarchy, there were a mixture of junior workers, supervisors, team leaders and senior managers.In terms of work experiences they ranged from 1 year to 25 years in the tuna industry. Work experience could have a lot of influence on their understanding of the HACCP system.

Permission was requested from the Cannery Manager for factory workers to be interviewed on site for 60 minutes. The interviews were conducted in a room onsite which was conducive to the participants. Culturally, Solomon Islanders are reluctant to express their opinions if they think they can be seen or heard by others.The participants in the interviews were unnamed, anonymity was maintained by ensuring themes were stressed and individual quotes kept to a minimum. No quotes, if deemed appropriate for use in the thesis, were linked to any one respondent by name.

This reduced the chance of information in the responses being linked with particular staff. Other cultural issues, such as access to participants, were considered, and are discussed in section 3.3.3.3.2.

Sample size was established using the ‘saturation’ principle, where once no new information is revealed at interview, no further interviews take place (Creswell, 2008).The *talanoa* methodology (Vaioleti, 2003) of conversation was adopted in the one on one exploratory interview. Saturation was reached at 11 interviews.

Talanoa is a word used in several of the native languages in the Pacific, especially in the Polynesian countries (Finau, 2010). *Talanoa* according to Havea (2010), refers to “three interconnected events, story, act of telling (of memories, longings, and more), and occasion of conversation (teasingly and critically, and usually informally)”. He went on to emphasise that, for *talanoa* to take place, all three interconnected events must occur at one time, and that is, “story, act of telling and conversation- together” (Havea, 2010, p. 11). Since then, the *talanoa* concept has been widely used by Pacific scholars and academics as a means of research protocol in accessing Pacific villages, and as a culturally appropriate methodology to be used in social research.*Talanoa* methodology is a Pacific culturally appropriate research method which expects researchers and participants to share not only their time and interests, but, also emotions (Otsuka, 2006).*Talanoa* asks researchers to establish a good interpersonal relationship and rapport with ethnic communities. It is a means of conversation, a talk and an exchange of ideas. “It allows people to engage in social conversation, which may lead to critical discussions, or knowledge creation that allows rich contextual and inter-related information to surface as co-constructed stories” (Vaioleti, 2003, cited in Fua, 2005, p.14). Given its cultural similarity and acceptability in the context of the Solomon Islands, *talanoa* methodology was adopted in the process of the one on one interviews. Ongoing field observation and diary recording of factory worker’s behaviour was conducted while in the factory.This helped to reinforce the interpretation of data collected during the exploratory interviews.

3.3.3.3.2 Qualitative data collection

An MP3 recorder was used to record the one on one exploratory interviews with the selected factory workers. Potentially the use of a MP3 recorder to record interviews could be inhibiting due to cultural difference. Verbal consent of the participant was sought and if not agreed, a field note book was used instead. However, all the participants in the qualitative interviews agreed to be recorded. Prior to the interview, information related to participant’s privacy, anonymity was given. A consent form (refer to appendix VIII) was signed when the participant had agreed to be interviewed. Cue questions (refer to appendix X) were used to keep the conversation alive during the interview until the participants exhausted his/her view on the influence of culture on implementing HACCP food safety system in the factory. Participants lived experience was the key phenomenon under study in the one on one exploratory (*talanoa*) interviews.

3.3.3.3.3 Qualitative data analysis

The recorded interviews in Solomon Islands 'Pijin' English were first transcribed verbatim in 'Pijin' English, then translated and transformed into English.It was considered better to translate into English after careful transcription of the 'Pijin' English, rather than to try and translate during the transcription process, in the belief that fewer errors would be incurred. The translated scripts, now in English, were cross checked by a fellow Solomon Islander to verify and validate that what had been translated corresponded to the 'Pijin' English transcribed scripts.The validated translated versions were then edited, corrected and transformed into written text in order to make them readily accessible and understandable (Sandelowski, 2000).

In the preliminary data analysis, transcribed texts were verified with the recorded interview to ensure that what was transcribed corresponded to the participant's response at interview. If there were inconsistencies, then amendments were made to ensure that what was transcribed corresponded to what had been recorded. Emerging themes were identified and derived from the one on one *talanoa* interviews.Thematic data analysis (Creswell, 2008),was used to analyse qualitative data.The process identifies themes and concepts in the data through certain comparisons, categorizations, interpretations, descriptions and synthesis (Ezzy, 2002).The process, as suggested by Creswell (2008), is to create meaning out of the text data, examine codes for overlap and redundancy, and collapse those codes into broad themes.This is an inductive process of narrowing data into few themes (Creswell, 2003). Due to time factor and distance, the transcribed and translated versions were not returned to the interviewees for double check. For purposes of verification the themes were identified both in the Solomon Islands 'Pijin' and English and, as a result of this, the same themes emerged.The themes were identified based on common key points being emphasised by the majority of the participants during the interview.

3.3.3.3.4 Qualitative (*Talanoa)* interview findings

From the analysis of the interview transcripts, the overall finding is that culture does have an influence on impeding the effective implementation of the documented HACCP system at Soltai Ltd. Four themes were identified and are discussed below. Quotes are used to illustrate the identified themes. In order to maintain the originality and exactness of the participant's view, excerpts from the transcripts of the interviews in the Solomon Islands 'Pijin' English *(lingua franca),* which is commonly spoken throughout the Solomon Islands, is first presented followed by the English translation. Presenting the written scripts in raw form will help maintain the rich meaning provided by the participants.

a) Conflict of local cultural practices versus organisational culture

Soltai Ltd, like any other organisation, has its own organisational rules and policy to adhere to. In order to comply with the EU requirements and the National Food Safety Regulation, Soltai Ltd being a food industry has a well documented food safety system in place. The problem is, that factory workers coming from the villages where there are no strict rules on personal hygiene are directly employed in the factory, and come in with their cultural practices, attitudes and behaviours. In most cases, these contradict the organisational culture, that is, company rules, regulations and policies as far as food safety is concerned. All participants highlighted the fact, that the local culture or ways things are done in their villages are different from the organisational culture. For example, one of the participants said;

"The problem mifala facem so far is, ia, culture is one big issue, people where come from villages,not necessarily villages,even school dropouts, wea oketa come wetem cultural background wea hemi, sometimes hem conflict wetem what nao iumi like for implementim, say HACCP system" (P12). "One of the cultural barriers notable in the factory is that different people come in with different background, and in most cases, the cultural practices or habits that workers come in with are in conflict with the HACCP food safety system principles" (P12 translation).

A common issue raised by all (n=11) participants was the ways in which cultural food preparation was carried out, in many cases in direct opposition to HACCP principles.All participants interviewed stated that, one of the major differences encountered on their first experience working in the factory was that, there is a systematic way of doing things in the factory.Personal hygiene rules are strictly enforced, unlike, in the villages where personal hygiene rules are not strictly adhered to when preparing food. Asked about whether or not they are aware of any traditional food preparation which has been influenced by more recent, or western, ways of food preparation, one of the respondents replied;

"Olsem mi lukim differens between tufala ia.why mi say hem differen, becos long hia mi kam mi waka, mi handlem kaikai, first something mi must swim , mi mas wash hand fastaem, after washim hand blong mi, rinsim baek before mi go holem fish nao ia. Which hem differen long kastom nao ia. Bata kastom, olsem what hem differen long diswan, jes anyhow nomoa, nomata iu no washim hand bata iu gogo het long wakem kaikai nomoa, olsem nao mi lukim what hem differens long tufala"(P3). "There is difference in the way we prepare food culturally as

compared to the way food is prepared in the factory. In the factory, there is a systematic way of doing things, and strict personal hygiene rules are enforced. Prior to handling fish, you have to wash your hands, rinse, before handling fish. Unlike, in the cultural way, where personal hygiene does not really matter" (P3 translation).

This statement is further reinforced by (P8) who states;

"Ia, wanfala differens mi lukim nao, long factory everytime olsem iumi practiciem hygiene, iumi kam insaed, iumi have to washim hand before iumi touchim things, but sometimes long home, oketa mothers ia, sometimes oketa go nomoa holem kaikai nao ia, oketa say hand blong oketa washim finish, oketa lukim no any dirty long hem, oketa holem nao, hao mi lukim samfala nao ia, or after oketa cook, oketa kaikai stap,ota no washim hand, oketa go sharem kaikai na"(P8) "One of the major differences is that personal hygiene rules are strictly enforced in the factory. Unlike in the homes, mothers do not really care about personal hygiene when they prepare food and serve food after cooking" (P8 translation*)*.

In contrast to this, (P2) commented that, it does not really matter whether or not food is prepared in a hygienic manner, and attests to this by saying;

"Oh, somehow olketa oldman before say, olketa kaikai olsem ia, iumi usim olsem,iumi live long, sapos iumi duim gud kaikai or handlem gud kaikai, bae iumi die quick taem"(P2). "There is a strong belief that we tend to live and survive longer when we adhere to our old ways of food preparation, as compared to modern ways of food preparation" (P2 translation).

A statement which (P6) supported by saying;

"Ating hem differen lelebet, why mi say hem differen lelebet, preparation long home, sometimes mi no wash hand bat mi go holem kaikai, mi kaikai nao. Ok mi comparem kam long factory, mi have to folom step, mi wash hand before mi holem fish,bat taem mi duim diswan long hom, body blong mi hem healthy nomoa"(P6) "The way food is prepared at home is different from the way food is prepared in the factory. At home, sometimes I do not wash my hands and prepare food, unlike in the factory where there are strict personal hygiene rules to follow. Although, I do not comply with strict personal hygiene rules at home in preparing my food, my body is still healthy" (P6 translation).

On the question of whether or not culture does have a strong influence on the implementation of the HACCP system in the factory, the participants had differing opinions. Seven out of eleven participants in the *talanoa* interview agreed that, yes, culture does have an influence on the workers' attitude and behaviour towards implementing the HACCP system in the factory.Three participants did not respond to the question and one participant thought that culture does not have any influence at all.

The following statement given by one of the participants illustrates that culture does have a strong influence on workers attitude and behaviour to change.The respondent emphasized that, as a result of implementing the HACCP system in the factory; it does help them to change their attitude and behaviour towards the importance of personal hygiene in food safety.

"*Mi ting ting blong mi hem olsem, long side long disadvantages, barava hem blockem nao way hao mifala should ready for preparem food, becos long places wea mifala come from, hard for mifala washim hand, hard for mifala wearem gud kaliko, hard for mifala mekem hair blong mifala gud then mifala preparem food, and that fala thing ia bae save contribute a lot long the way mifala preparem kaikai, mifala distaem, mifala come long hia, olsem mifala save nao hao na bae mifala preparem mifala seleva, for mifala save go long place fo mekem kaikai, so mifala save ready. Hemi givim mifala gud fala ting ting and idea mifala save herem about disfala what iu talk about long mifala, HACCP food safety system ia". (P9) "I have a strong belief that culture has a lot of disadvantages and is a barrier to enhancing food safety. For example, at home, we do not wash our hands properly before preparing food, we do not wear good clothes and we do not wear hair nets when preparing food. Now that we are working in the factory, we learn a lot of things, like how to keep our bodies clean, how to wash our hands and wear clean clothes prior to handling food.It broadens our knowledge and understanding of what HACCP is all about and the importance of HACCP principles in food safety"* (P9 translation).

When asked whether or not attitude does link with the local culture, all participants said yes. Attitude and culture have a close relationship, as can be best summarised by one of the respondents who stated that;

"Ia, ia, I think hem playem that one, tufala kam inline, say like, I say to you that, culture is not a big thing, but I may be wrong, so I might take back my own words for that, because culture too hem contribute to long attitude blong oketa people".(P13). "Yes, culture plays a major role in influencing the workers attitude towards change" (P13 translation).

Another respondent commented;

*"Olsem, sapose mi duim waka olsem ia, sometimes, mifala waka man insaed ia, tingting tumas nao hao fo duim kaikai long home, mifala kam long hia, sometimes mi forget nao fo duim wat olketa talem mi, olsem hem lelebet hat fo mi, olsem mi ting back yet long local wan blong mi yet ia"(P3) "Because of strong cultural influence, we tend to stick to our local way of food preparation and forget to wash our hands prior to handling fish"(*P3 translation)

Another major issue is the changing of workers' attitude and behaviour.Since they are accustomed to their cultural practices at home, it makes it more difficult for them to quickly adapt to change. One of the participants said that;

"The only big ting olsem big challenge mi lukim long hia nao hem attitude, attitude blong people, it's nothing to do with culture but it's something to do with their attitude.But it's the attitude of some people that, hem lelebet hard fo iu changim ia, so the only way we can do that here is to discipline people. for example; they know that it is in the rule that they shouldn't smoke in areas where hem no designated for smoking, but they still continue to do that, they are not sapos to chew beetle nut, but they continue chew beetle nut, it's attitude ia, they know that oketa should no duim that wan, so the only thing nomoa fo mekem hem waka nomoa, is to discipline people. That is the biggest challenge mi lukim fo implementim HACCP long Solomon, it's the attitude of the people" (P13). "The biggest challenge I see in the implementation of HACCP in the factory is the attitude of the workers. There are some workers in the factory that cannot change their attitude, and the only way is to discipline them.They know that it is not allowed to smoke or chew beetle nut within the premises of the factory, but they continue to break the rules" (P13 translation).

When asked whether or not they thought the local culture is a barrier to implementing the stringent HACCP food safety system in the factory, four participants responded 'yes', five participants did not respond to the question and two participants responded 'no'.

For those who said 'yes' most of them commented that;culture is a barrier to the implementation of the HACCP food safety system as it is difficult to merge old cultural practices with the modern HACCP principles.The following illustrates a common response from participants; (P4);

"*Culture hem olsem wanfala wall wea hem blockem nao gud way for karem aot disfala HACCP food safety system ia"* (P4). *"Culture, is like a wall that impedes effective implementation of the HACCP food safety system" (*P4 translation).

Cultural taboos and reluctance by the workers to fully inform their supervisors of their health condition is also a significant cultural barrier that inhibits effective implementation of the HACCP food safety system in the factory. Five participants stated that due to the influence of cultural practices, female workers are not confident to honestly report their health conditions to male supervisors or nurses and vice versa.This is highlighted by one of the participants, who said that;

"Example, one area nao side long sanitary measures, wea iumi wande talem olketa, that iu have to washim yourselves and olsem, and since there is a cultural barrier wea iumi sometimes even up to the supervisory level hard for addressem that situation, wea olketa say, iufala have to cleanim body blong iufala, part olsem hemi cultural barrier lelebet ia. Certain areas insaed long olketa principles ia, bae cultural barriers hem come in.Because sometimes olketa people sick, but oketa same fo talem wat nao sick blong olketa, so olketa something olsem, oketa come in and go,so olketa GMP sometimes hemi problem nao,because hem onefala cultural something" (P12) "Cultural taboos and reluctance to be honest, to inform the supervisors or nurses of their health problems (sickness) is a setback to effecting the HACCP system in the factory.This is due to cultural barriers that exist within the organisation.For example, men should not know the private matters of women and vice versa" (P12 translation).

Nine participants thought frequent changing of workers is a hindrance as there will always be new people coming in with behaviours which reflect their cultural norms.Two participants did not respond to the question. The role of worker turnover can be best summarised by one of the participants who stated that;

"The other problem kam in nao, labour turnover.Sometimes mifala tekem people, training oketa,new people come in moa,hem wetem cultural something ia come back moa.then oketa people ia go long home,oketa wande come back,oketa tekem moa oketa village way or traditional way blong oketa, so awareness hem nomoa only way fo over comem oketa something and control inside long factory,quality control.Hem nomoa mainly long cultural side" (P12)."Labour turnover is also a factor that contributes to enhancing cultural barriers to impeding the HACCP system.Due to frequent labour turnover, there are always new people recruited in the factory to clean fish, as such, there will always be new people with cultural norms coming into the factory. The former workers, when they return to work in the factory will again come back with the cultural habits, so there will be issues of cultural conflict/barrier in the factory" (P12 translation).

b) Culture and illiteracy impedes understanding of HACCP principles

Another important factor which ties in with potential cultural barriers is the educational background. All participants (n=11) in the interview highlighted that culture and illiteracy were the major factors that influence the effective implementation of the HACCP food safety system in the factory. The fact that the HACCP system is documented in English makes it difficult for them to understand it well, as most of the factory workers are primary school leavers. Also, most of the participants reported that, they had heard about HACCP, but they did not really understand what HACCP is all about.Whether or not the workers actually understand the messages put to them is clearly an issue, best demonstrated by one of the participants who stated that;

"Hao na people recieivim, hao nao people ia getem nao message, hem onefala something tu. Hem onefala educational background and onefala is cultural background. Culture in a sense that hemi putim oketa people fo lay back lelebet fo tekem in what nao need or what nao requirement,oketa tings olsem".(P12) *"The workers educational background also plays an important part in their understanding of the HACCP principles.How the workers grasp and understand the message relayed is another factor. Culture and education goes hand in hand in this sense.Culture, in the sense that, it draws them back to accept changes or adhere to the HACCP principles"* (P12 translation).

c) Women are involved a lot in food preparation

In the context of the Solomon Islands culture women are the ones commonly involved in food preparation. All participants (n=11) stated that women were the ones who are mostly involved in preparing food for the family.This reinforces the important role women play in food preparation in a male dominated society. However, in terms of decision making, they are not involved. This inequality in decision making is a barrier to positive change. The trend in most food industries in the Solomon Islands reflects the same, more women are employed in food industries than men. However, male dominance in decision making (or not wanting to listen or adhere to instruction given by their female supervisors or managers) is one of the cultural barriers encountered in the factory. Five participants said "yes" male dominance is prevalent in the factory. In most cases they do not always want to listen to instruction given by their female supervisors. Along the same lines, four participants noted that, they do not mind who their supervisors are, so long as the job is done. Two participants stated that they always comply with their female supervisors. Evidence for this comes from a response by one of the participants who said that;

"Ia, especially long society blong iumi where male hem dominance, that male they don't want to listen to ladies taem talk ia. So that's the biggest challenge mifala facem, like it's hard, sometimes hem challenging, bae iu facem challenges, but as iu continue to givim awareness, people tend to understand"(P13). *"One of the challenges I faced in our society and culture is male dominance in decision making. In that, I find it difficult and challenging to give orders to men, as they do not always want to listen to female supervisors.However, given continuous awareness and training, male workers started to adjust and follow instructions given by female supervisors"* (P13 translation).

Consistent with this, (P1) stated;

"*Whether hem female supervisor or male supervisors, mi no garem problem nomoa, so long as waka ia hem done" (P1)." I am not concerned at all whether she is a female supervisor or male supervisor, so long as the work is done" (P1 translation).*

d) HACCP principles can complement cultural practices

While cultural practices were apparently opposed to the implementation of HACCP principles, especially with regards to personal hygiene, a few participants (n=4) suggested that the HACCP principles can complement the cultural practices. For example, the pre-requisite programs which include SSOP/GMP once enforced in the homes can complement cultural ways of food preparation. This point was confirmed by (P8) who stated;

"*Long tingting blong mi, culture and kastom blong iumi hem no barrier. Olsem hem mekem fo iumi needim change tu ia, olsem something iumi no save fo iumi change then iumi adoptem, oketa what hem important fo iumi should duim, fo safety blong ota kaikai blong iumi long home tu wea iumi save kaikaim"* (P8*). "In my personal opinion, our culture is not a barrier. It helps us to change.For example, it helps us to learn new things and we adopt new things that enhance food safety in our homes"* (P8 translation).

Furthermore (P5) added to this by saying;

"Long general view blong mi, hem gud that iumi practisem long home ia,so that disfala HACCP system hem waka ia.Olsem hem mas effective long ples iumi live and ples iumi work olsem ia".(P5) " In my opinion, I think it's good that we practice HACCP at home. For HACCP to be effective,HACCP must be implemented in our homes as well as in our place of work" (P5 translation).

Similarly (P2) comments on this further;

"*Oh ia,olsem ting ting blong mi nomoa,olsem HACCP should go nomoa and helpem nomoa, custom way fo forget nomoa olketa custom way. Tekem new way (HACCP) and maretem wetem oldway (custom) way fo improvem and strengthen nao way iumi preparem kaikai. Hem save wok long tufala way ia" (P2). "Yes, in my personal opinion, incorporating HACCP principles into the local culture would improve food safety and hygiene" (P2 translation).*

Based on the findings of the four themes identified, there was very strong evidence to show that culture and illiteracy plays a major role in impeding the effective implementation of the HACCP food safety system in the Soltai Ltd factory.

3.3.3.3.5 Discussion

In the qualitative *talanoa* interview, culture and low literacy due to lack of education (illiteracy) proved to be the main contributing factors to the barrier to the adherence and implementation of the HACCP principles in the factory.While the author fully appreciates the Cognitive and Behaviour to HACCP Adherence Model developed by Gilling, et al. (2001) and adapted by Azanza and Zamora-Luna (2005) as the major framework used to determine barriers to implementing HACCP in the factory, this study revealed that the model fails to take into consideration other socio-cultural factors (culture and education) which are major determinants influencing knowledge, attitude and behaviour of factory workers in a developing country like the Solomon Islands. This is where there is a need to fully explore the pre-disposing factors that could influence knowledge, attitude and behaviour in a more holistic manner. As in the context of the Solomon Islands, the pre-disposing factors (culture and education) are major factors that influence, workers, awareness, familiarity and comprehension and application of HACCP in the factory.

Overlooking these socio-cultural factors or pre-determinants indicates that, the model is not taking into consideration the "root causes" of the issues that could have great influence on the implementation of HACCP principles in the context of the Solomon Islands.The findings of the survey research and qualitative one on one *talanoa* interviews reinforce that culture and illiteracy (low education) are major barriers to the implementation of the HACCP principles at Soltai Ltd (refer to figure 24 & figure 29).The results of the non experimental research (refer to figure 11) further reinforced the above, as cultural habits and low education no doubt play a major part in why workers did not wash, rinse and dry their hands properly. It is based on these socio-cultural pre-conceived views that a modified Cognitive and Behaviour to HACCP

Principle Adherence Model in the context of the Solomon Islands has been developed as illustrated in figure 31.

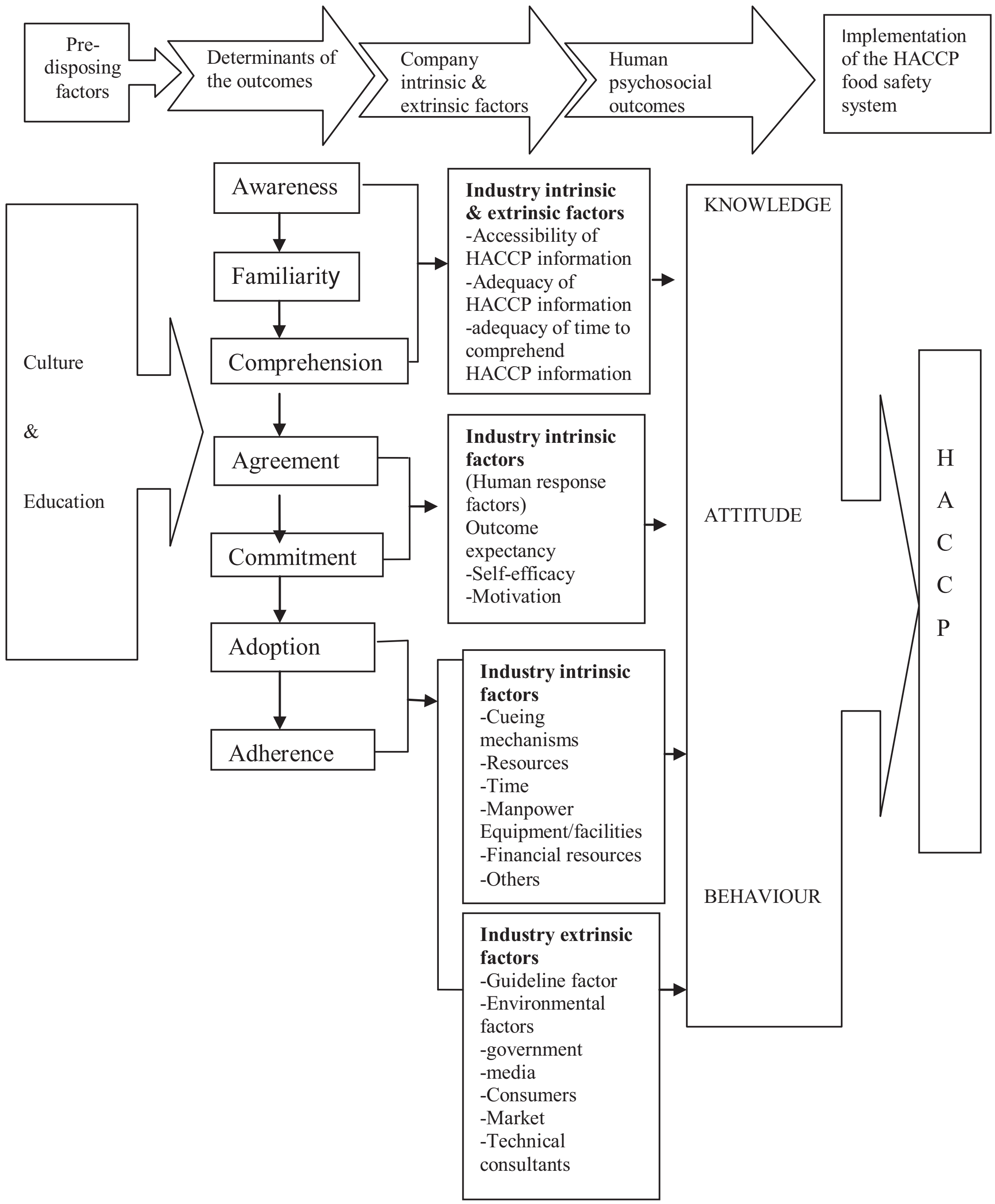


Figure 31: Modified cognitive and behaviour to HACCP principle adherence model in the context of the Solomon Islands. Source: adapted from Azanza & Zamora-Luna (2005).

Figure 31 illustrates the modified Cognitive and Behaviour to HACCP Principle Adherence Model in the context of the Solomon Islands.What it means is that, implementation of the HACCP food safety system is influenced by the pre-disposing factors (education & culture) that will in turn influence the determinants of the human psychosocial outcomes (awareness, familiarity, comprehension, agreement, commitment, adoption and adherence). Along with the influence of the company intrinsic and extrinsic factors, it will influence the human psychosocial outcomes that in turn will determine the effective implementation of the HACCP food safety system in the factory.Therefore, in the context of the Solomon Islands, in order to determine effective implementation of the HACCP food safety system, it is important to consider an holistic approach involving all factors which impede the system.To address food safety issues or (HACCP) in the context of the Solomon Islands, one would have to start by tackling the pre-disposing factors and follow suit.Overlooking the "root causes" of the problems (pre-disposing factors) will not solve the problem holistically.

Based on the results of the survey research and the qualitative interviews, education and culture stood out very clearly to be the major factors that influence, knowledge, attitude and behaviour, and therefore may impede the implementation of the HACCP food safety system at Soltai Ltd. Education plays a positive role in acquiring knowledge, comprehension and safe food handling practices (Campbell, et al., 1998; Cotterchio, Gunn, Coffill, Tormey, & Barry, 1998). In terms of educational level, the majority of the cannery workers reached primary school level (standard 6) as the highest level of education.This could also be a major contributing factor to lack of awareness and familiarity with the HACCP principles and the pre-requisite programmes (SSOP/GMP) (refer to figure 16, 17 & 19). A similar study conducted by Azanza and Zamora-Luna (2005) using the same model also revealed similar results.Their study revealed that, the educational background of the HACCP team members was quite diverse. There were those who completed tertiary education.Others, however, were only able to have vocational training and some primary education.For those teams consisting of mostly under-educated members, technical difficulties in acquiring knowledge and transposing these into implementable activities were encountered (Azanza & Zamora-Luna, 2005).The apparent educational inadequacy of some of the members of the teams were further aggravated by the fact that small companies may have limited access to HACCP information and provide less resources for skills development (Taylor, 2001).The study showed that most of the respondents were not aware of HACCP principles and tasks.Familiarity was the highest knowledge level achieved among the respondents.The study further revealed that, the current HACCP knowledge level of the respondents may be due in part to the inadequate and inappropriate information dissemination systems available within the country (Azanza & Zamora-Luna, 2005).

The same is largely true in the context of the Solomon Islands. Although HACCP principles gained importance in the country during the late 1990's and early 2000, its applicability and full acceptance by all food industries in the country was not realized. It was only when Soltai Ltd started exporting tuna loins to the EU that, the HACCP principles re-surfaced and gained greater significance and implementation in industry increased.Slow implementation of HACCP was undoubtedly influenced by the delay in the formulation of the food hygiene regulation and food safety policy in the Solomon Islands. Even though HACCP implementation has now become a mandatory requirement by law for all food manufacturers in the Solomon Islands, its dissemination and thus people's awareness of it is progressing very slowly.This is compounded by lack of technical expertise on food safety and the inadequate and inappropriate information dissemination systems available in the country.

Similar studies conducted by Gilling et al. (2001), identified lack of awareness of the HACCP principles as one of the technical barriers restricting HACCP guideline adherence in U.K. food processing establishments.Likewise, a study conducted by Herath and Henson (2010) on the food processing sector in Ontario,Canada,highlighted the need to raise awareness of the weaknesses of established food safety controls and the importance of information dissemination and training to overcome the barriers that impede the implementation of HACCP food safety system in food processing sectors in Ontario.

The result of this study revealed the same at Soltai Ltd (refer to figure 19).Although Soltai Ltd has a well documented HACCP food safety system in place, it appears that the workers do not really understand what HACCP is all about or what their role is in effecting it.

Access to sources of information for the workers in the factory is limited to: workshops or seminars; awareness programmes conducted by the quality control department; Government Departments dealing with food safety; or external consultants on seafood safety.If all these were carried out effectively, they may be enough to make a big difference to the implementation of HACCP food safety system in the factory.

In a country like the Solomon Islands, where culture is inbuilt in the daily lives of the people, culture will of course be a major factor that would influence the workers' attitude and behaviour towards HACCP food safety in the factory.This was revealed to be a major factor in the one on one *talanoa* interviews in which most participants stated that culture is a major barrier to effective implementation of the HACCP food safety system in the factory.In addition, culture in conjunction with illiteracy (lack of education and having basic understanding of science and the relationship between bacteria and poor sanitation and how it can spread food borne diseases), were the major factors that influence workers attitude and behaviour.

There seems to be a strong relationship between culture and the workers' attitude and behaviour,which in turn affect the workers' motivation, commitment, adoption and adherence to the HACCP food safety system in the factory.For example, workers' commitment to implementing the SSOP/GMP's is important in ensuring the effective implementation of the HACCP food safety system in the factory.However, the fact that a high percentage of the participants (refer to figure 22 & 23) were not fully committed and motivated to implementing HACCP principles in the factory is of great concern.Lack of motivation and commitment would risk the safety of the tuna products processed in the factory.Successful implementation of the HACCP food safety system, requires an understanding of its principles and commitment to it through all levels in the workforce (Bas, et al., 2007).

In the context of the Solomon Islands, the local culture plays a major role in the workers' lack of motivation and commitment, as it is difficult to change attitude and behaviour when people have already grown up under a different cultural circumstance.For example, workers' resistance to change is an issue in the factory.This could well link with their cultural beliefs and could be the reason why participants in the qualitative interviews (refer to P2 & P6, p96), thought that whether or not food is prepared in an hygienic manner, does not matter and this indicates resistance to change. This reflects a culture and mindset that will take time to change for factory workers who come direct from villages to work in the factory.This is where the challenge lies in effecting change especially when implementing the HACCP principles which are new to them.

Furthermore, inequality in decision making is a barrier as highlighted in the interviews that mentioned that male workers do not want to listen to their female supervisors. The Solomon Islands is a male dominated society and this is evident in nearly in all walks of life that women are answerable to men.The '*Big man'* system in the context of the Solomon Islands culture (Sahlins, 1963; Sikua, 2002), where men are referred to as the custodians of the local culture and warriors have an influence on this mentality.This gender inequality in decision making is notable in the Solomon Islands as currently there are no women representatives in key decision making bodies of the country such as the National Parliament, and where no woman has been elected into the honourable house.It is therefore, difficult for women supervisors to give orders to men because of this conflicting view that women are answerable to men and should not give orders to men.

While culture and illiteracy (low education) are major barriers to the implementation of the HACCP food safety system in the factory, on the other hand, the introduction of HACCP in the factory has also brought about positive changes to the lives of the workers (refer to figure 25 & 26).This is evident in some of the qualitative interviews where one of the participants commented that;

"Now that we are working in the factory, we learn a lot of things, like how to keep our bodies clean, how to wash our hands and wear clean clothes prior to handling food"(P9 translation).

Furthermore, this is supported by Henson (2002) who states that, one of the major benefits of having implemented HACCP is increased awareness among staff of food hygiene/safety issues. This in turn further enhances staff motivation to maintain and develop further food safety controls.However, whether or not there is a positive influence of HACCP on the lives of those working in the factory at Soltai Ltd, as a result of learning new skills such as good hygiene practices and food safety, needs to be fully explored in the context of the Solomon Islands.It would be interesting to find out more about the impact of HACCP system in the homes and village settings of factory workers.

CHAPTER 4 - SUMMARY DISCUSSION

By adopting the mixed methods methodology, quantitative data was obtained from the chemical (histamine), microbiological (total coliform, total microbial load/TPC & *E.coli*), descriptive analysis of GMP, and survey of HACCP knowledge and implementation. The qualitative data was derived by conducting one on one exploratory (*talanoa*) interviews with the workers.

The review of the GMP on board the fishing vessels showed that NFD Ltd as far as histamine control is concerned is in compliance with the EU Regulation EC 853/2004 and the Solomon Islands Pure Food (*fishery products)* Regulation 2005.However, GMP alone does not indicate that the principles of HACCP are fully complied with. The SSOP/GMPs always go hand in hand as pre-requisites of the HACCP principles.A sanitation standard operation practice includes personal hygiene and all other pre-requisite programs to enhance food safety and maintenance of GMP on board the fishing vessels.This is an important area worth exploring which was not investigated because permission was not granted by NFD Ltd to conduct the study on board the fishing vessels.It would be interesting to determine compliance and how culture could influence personal hygiene and food safety issues on board the fishing vessels, knowing very well that most fishermen are recruited direct from their home villages without any form of training on personal hygiene and food safety or HACCP.

Furthermore, while NFD Ltd has a well documented HACCP food safety system in place, records reviewed from the CA audits (refer to table 4) and interviews conducted with the Government Auditors highlighted that NFD Ltd needs to strengthen the implementation of their documented HACCP manual on board the fishing vessels.There is a great need for the workers, both off shore and on board the fishing vessels to fully understand the HACCP principles, to appreciate their role in the food safety process, and be committed to the implementation of HACCP.Implementing what is documented in the HACCP manual has been one of the key areas that NFD Ltd failed to comply with as per the CARs issued to the company (T. Mamupio, (personal communication, September 27, 2010) and (J.Reynolds, personal communication, October 28, 2010).Based on the records reviewed, it appears the company is working to improve the defects noted.There is need to carry out more training awareness programmes on board the fishing vessels especially on SSOP/GMP.HACCP is not a stand-alone system, but incorporates the pre-requisite program which includes the SSOP/GMPs.

The histamine and microbiological results (total microbial loads as indicated by TPC and *E.coli*) are within acceptable limits as per the EU directives EC 2073/2005 and the Solomon Islands Pure Food *(fishery products)* Regulation 2005 (European Parliament, 2005; Pure Food (*fishery* *products*) Regulation," 2005) at the time of the research.However, the presence of significant numbers of microorganisms as indicated by total coliform results on food handlers' thumbs after washing (refer to figure 11) showed that there is great need to educate the workers on the proper procedures to wash, rinse and dry their hands to avoid cross contamination of the tuna loins from microorganisms on their hands.This, is probably associated with lack of training on HACCP principles and food hygiene (refer to figure 18), lack of awareness of the HACCP principles (refer to figure 19), and due to inadequate HACCP information available in the factory (refer to figure 20).Culture and low education (illiteracy) clearly play an important role in the workers'complacency along with lack of motivation due to industry intrinsic factors such as lack of training on HACCP principles and food hygiene.

The results and findings of the survey questionnaire research showed an interesting and contradicting view of the workers understanding and attitude/perception of the implementation of the HACCP food safety system in the factory.While the majority of the workers at Soltai Ltd do not understand the HACCP food safety system well, the study showed that the workers do have a positive attitude towards HACCP (refer to table 9).This goes to show that the workers, regardless of limited knowledge and understanding of the HACCP food safety system in the factory are complying because it is mandatory for them to comply since it is a company rule enforced in the factory.However, the rationale and the importance of why they are doing things (example, washing of their hands, rinsing and drying their hands effectively) are not well understood.This is where the need for continuous training and awareness of good personal hygiene practices including HACCP principles are vital for the workers in the factory.Ignoring this would lead to workers being complacent of adhering to the SSOP/GMP's in the factory and reverting to their local cultural practices which in most cases are opposed to the company HACCP food safety system as highlighted in the qualitative interviews.

One notable behaviour observed in the factory is that fish cleaners when getting tired,sing songs.This is unacceptable behaviour in food processing factories such as Soltai Ltd as microorganism which are present in their saliva would contaminate the tuna products.It was observed that Soltai Ltd workers used the area behind the social amenity as a designated place to smoke.The cannery should adopt a smoking free environment policy in order to promote personal hygiene and discourage workers from smoking.It is notable that those seen smoking are still wearing their working uniforms, which is unacceptable behaviour to be practiced for those working in food industries.There is high risk of cross contamination of the tuna products from their uniforms as they will return to handle tuna products with the same uniforms on. These unacceptable behaviours and poor personal hygiene attitudes are closely associated with their cultural behaviour from home.Therefore, there is great need to reinforce to the Soltai Ltd management that company SSOP/GMPs must be strictly adhered to, and more education and awareness training be conducted to address the unacceptable behaviour of smoking within the company premises.

The use of *talanoa* method, a culturally acceptable research approach in the context of the Solomon Islands culture in the one on one qualitative interview further enhances the mixed methods study.The *talanoa (story telling, conversation, or exchange of ideas)* (Fua, 2005), approach explored in depth the factors that impeded the effective implementation of the HACCP food safety system at Soltai Ltd.The exploration of the workers' first hand experiences in the factory in adapting to the modern (Western) way of food preparation, which in most cases is opposed to local cultural way of food preparation, was at the heart of the *talanoa* interview. The *Talanoa* approach is multi-disciplinary.For example, it can be used in the village settings, in the business world (Prescott, 2008), peace building (S. Halapua, 2007), research design in education (Otsuka, 2006), religion (W. Halapua, 2003) and (Havea, 2007), therefore, *talanoa* in itself can cross borders, is complex and flexible (Havea, 2010).Havea went on to emphasize that "orality is at the heart of *talanoa*.*Talanoa* will not die if they are not put into writing, but, *talanoa* will die if they are not remembered" (Havea, 2010, p. 17).

It is not the intention of this study to deliberate extensively on the *talanoa* concept, but, the approach was adopted in the qualitative phase of the study because of its cultural appropriateness and acceptability in the context of the Solomon Islands.*Talanoa*, on the other hand, are never ending, so long as there are food safety issues at hand, the concept of *talanoa* will continue.This study may have unwrapped some baseline information/factors that impede the effective implementation of the HACCP food safety system at NFD Ltd and Soltai Ltd, but the process of *talanoa* on food safety issues will be never ending.Therefore, as the term implies, let us keep the *talanoa* spirit flowing in the food industry to ensure food safety and consumer confidence.

The qualitative *(talanoa)* interview results revealed that cultural way of food preparation and practices in most cases are opposed to modern way of food preparation.For example, there is systematic ways of doing things in the factory, and personal hygiene rules are strictly enforced in the factory.It is a must to wear uniforms, hair nets, gum boots and no jewelleries or excessive use of deodorants are allowed in the fish factory.Unlike in the local settings (villages) where things are done on an adhoc basis and personal hygiene is not strictly enforced.

It also further shows that illiteracy and culture are major factors that influence effective implementation of the HACCP principles in the factory.These are notable and evident in the unacceptable behaviours practiced as discussed above.

Overall, the study revealed that there is correlation between the findings of the non experimental research, survey research and the qualitative (*talanoa*) interview research.For example, the findings of the survey research and qualitative interview reinforces that culture and low education (illiteracy) are the major barriers to the implementation of the HACCP principles at Soltai Ltd.This is evident by the significant total microbial load (as indicated by TPC) at all four sites in the processing chain.Therefore, sequential triangulation of findings, confirmed in this study, reinforces the view that mixed methods research is indeed an appropriate method of choice for a study such as this to determine compliance and psycho-social behaviour (knowledge, attitude and behaviour) in food industries (Hanson, Clark, Petska, Creswell, & Creswell, 2005).

Ultimately, the contrasting quantitative and qualitative approaches adopted, formed the framework of the mixed methods methodology used. Furthermore, Armour et al. (2009) stated that "methodological stringency and accuracy of the results are related, because solidity in methods provides greater assurance that the findings are valid" (Armour, et al., 2009, p. 102). This is further supported by O'Cathan and Thomas (2006) who say, that one of the reasons why mixed methods approach is applied in health research is that it can provide a bigger or richer picture of the issue under study.This study confirmed that, mixed methods research is an excellent means for deriving quantitative (non experimental) data, which complements information on psychosocial behaviour (survey questionnaire and qualitative interview) in food safety and quality assurance.

CHAPTER 5 - CONCLUSION

In conclusion, the overall implementation of the HACCP food safety system at Soltai Ltd and NFD Ltd companies, at the time of conducting this research study, to some extent were in compliance with the EU requirements (EC 852/2004, EC 853/2004, EC 854/2004) and the Solomon Islands Pure Food (*fishery products)* Regulation 2005.There are, however, also alarming results revealed by the non experimental research.For example, the significant number of microorganisms (as indicated by TPC) at all four sites in the processing chain and on food handlers' thumbs, and the high proportion (43%) of participants in the survey research who indicated that they only comply with HACCP system "sometimes" and "never", signals a potential food safety risk.Furthermore, some of the respondents to the qualitative *(talanoa)* interview stressed the point that workers are not washing their hands properly before handling food.

Therefore, the companies (Soltai Ltd and NFD Ltd) should not be complacent, but should strive to maintain the standard (and even further improve it) in order to keep meeting the stringent EU requirements for fishery products exported to the EU. The Fisheries sector is now one of the major exporters of commodities that contribute positively to the gross domestic product of the Solomon Islands. Therefore, it is pivotal that all stakeholders, including the food industries, work collaboratively to enhance food safety.The study revealed that the HACCP food safety system is a feasible system that effectively enhances food safety in the tuna industry, and it can only work through a collaborative effort by all stakeholders involved in the food chain, from the fishing vessels during harvesting through to the processing factory, and the final product shipment.Management commitment and workers motivation and compliance are also paramount to the successful implementation of the HACCP food safety system in the tuna industry.

The study highlights that education and culture were the two pre-disposing factors in the context of the Solomon Islands that influence, knowledge, attitude and behaviour of the workers, which in turn affects the effective implementation of the HACCP food safety system at Soltai Ltd and NFD Ltd.And these very firmly point to a level of ignorance (knowledge) on the part of workers, and in some cases lack of adherence in practice (due to culture and illiteracy).

While, formal education is a matter beyond the control of the company management, continuous education in terms of providing informal training and awareness on aspects related to the HACCP food safety system, and good hygiene practices, can be carried out at the factory level. Emphasis should be on the fish cleaners whose important role, in effecting the HACCP principles in the processing factory, is in most cases overlooked.

Culture, on the other hand, can also be best addressed through continuous training and awareness on the importance of personal hygiene in food safety.The challenge lies in the fact that people cannot change attitude and behaviour overnight.However, stressing the important role they play in food safety and the repercussions of not complying with company rules and regulations will enhance the workers mindset to allow a change in attitude and behaviour.

The strength of the study lies on the triangulated approach adopted, as each phase of the study complements each other and are inter-related.Thus, this approach gives a holistic view of the implementation of the HACCP food safety system in tuna processing in the Solomon Islands from source to product shipment.

5.1 Limitations of the study

- Cultural differences, given participants came from many different villages and islands, have been major factors in this study, even though I am an indigenous Solomon Islander.This was overcome through maintaining cultural sensitivity, participant anonymity and having mutual respect between the researcher and the participant.
- Translation of the questionnaires from Solomon Islands 'Pijin' to English and vice versa is time consuming.Due to distance and time factor, recorded data that were transcribed, translated and transformed into written text in order to make it readily accessible and understandable were not returned to the respondents to be verified.
- Unfortunately access was not granted to NFD Ltd fishing vessels for reasons only known to the company, therefore I was not able to conduct the survey questionnaire with the Chief Engineers and Captains of the fishing vessel and was unable to access the SSOP/GMP records on board the fishing vessels.
- Due to break down of the spectrophotometer to analyse histamine, the Neogen histamine alert test kit was used instead of the recognised quantitative method.The alert test kit only gives qualitative data and not quantitative data that would enable comparison and drawing of conclusions about whether or not histamine build up has any relationship with microbial contamination - one of the objectives of the study.
- The delay in analysing the tuna samples for microbiological parameters could also affect the reliability and validity of the microbiological tests.It takes about a month for the tuna loin samples to be analysed at the laboratory.The samples were stored frozen in the freezer which could kill some of the microbes.
- The breakdown of the stomacher machine to macerate tuna samples to analyse microbiological parameters could also affects the homogeneity and consistency of the method adopted.As ordering spare parts would have prolonged the microbiological analysis, the homogenizer had to be used to macerate the remaining 19 samples.

- As noted earlier in the discussion on TPC and *E.coli,* samples had to be sent via plane from the processing plant to the laboratory, and delay in transportation could have affected viability of bacteria in the samples and thus results.This is the only and quickest means of transport in the Islands and is the usual practice to send samples to the NPHL in Honiara.
- Though, there was a good response to the number of participants participating in the survey research and qualitative interviews, high percentage (approx 30% on all survey questionnaires) of non response to the survey questionnaires is a limitation.This could be due to low literacy level, that the participants do not really value the importance of such studies, or that they do not really understand the questions well, even though the questions were translated into the Solomon Islands 'Pijin' English.

5.2 Recommendations – company improvements

In view of the above achievements, challenges and constraints encountered during the study, the following recommendations are put forward for further consideration by Soltai Ltd Company to further improve the HACCP food safety system in the factory and Competent Authority that deals with food safety in the country.Further areas of research are also recommended for those interested in the field of food safety and quality assurance.

- There is a great need for continuous awareness training on food safety, personal hygiene and HACCP in general, to be conducted in the factory.Priority training should be focused on the production workers (fish cleaners) who have not undergone any intensive form of training on food safety, personal hygiene and HACCP. They are the ones who handle the fish product on a daily basis, yet these people are often overlooked despite the important role they play in the processing factory.One or two days induction training on food safety in general, including HACCP principles, and the pre-requisite programmes (SSOP/GMP), should be conducted prior to recruitment.This should replace the 30 - 60 minute awareness talk normally conducted with new fish cleaners/factory workers in general, prior to recruitment.
- In order to adequately monitor process compliance with the Pure Food (*fishery products)* Regulation 2005 and the EU Directives, the need to adequately set up the microbiological unit of the Soltai Ltd Quality Control Laboratory with proper trained personnel, is of high priority.This will enable effective internal monitoring of the company HACCP system to ensure food safety and quality assurance in the processing plant.
- There is a great need to provide adequate HACCP information to the companies to enhance food safety.This is an area where industries and stakeholders such as the CA

should play an active role to ensure that HACCP information is made available and accessible to food industries.The information provided must target the different groups of the workforce taking into consideration their cultural and educational background.It is therefore, prudent for some of the HACCP information/materials be translated in the Solomon Islands 'Pijin' English, (*lingua franca)* commonly spoken and understood by all Solomon Islanders to ensure better understanding of the HACCP principles and the pre-requisite programs.

5.3 Recommendations- future areas of research

- This study is the first of its kind to be conducted in the Solomon Islands on evaluating the implementation of HACCP principles in the food industry.Thus it forms baseline information and data that food industries and the food safety authorities could adopt to develop a framework whereby food policies can be developed to strengthen food safety and quality assurance in the Solomon Islands.
- In a national context, the study has highlighted some very important issues to be dealt with in a broader context as far as food safety in the country is concerned.It is therefore, appropriate for further research studies to be conducted on similar food industries or in small and medium enterprises (restaurants, hotels or cafes) to determine the application of HACCP food safety system in a national context.
- A thorough sanitation study should be conducted from source to product shipment to determine likely sources and routes of contamination in the Soltai Ltd factory.This should also include both aerosol sampling on the ventilation system in the factory, water supply and environmental sampling on food contact surfaces.This will help to evaluate effectiveness of the detergents used in the cleaning process in the factory and identify routes of contamination in order to minimise microbiological contamination of tuna products in the factory.

5.4 Personal reflection

Notwithstanding the limitations encountered during the course of the study, on a personal note, as a new researcher in the field of environmental health, the hardships and challenges I underwent during the process of undertaking the study have been a worthwhile experience for me.I came to appreciate that, conducting off shore research especially in the remote Pacific Islands countries like the Solomon Islands, where resources are scarce and technical expertise are lacking, is indeed very difficult, frustrating and stressful.Furthermore, conducting research in companies whereby compliance issues are dealt with was challenging and difficult, as one company was unwilling to relay sensitive information that, presumably, could have repercussion for their operation.Company policies on relaying of information to a third party were a major factor.Overall, the experiences that I undertook during the course of the research study have further broadened my knowledge and understanding of the research process.It was indeed challenging but a satisfying and worthwhile adventure to undertake.

CHAPTER 6 - REFERENCES

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Appendix I MUHEC approval letter

MASSEY UNIVERSITY

1 June 2010

Mr Ernest Kolly
12/95 Randwick Road
Moera
Lower Hutt
WELLINGTON

Dear Ernest

Re: HEC: Southern B Application – 10/12
"From boat to bowl" – An exploratory study of the implementation of the Hazard Analysis Critical Control Point (HACCP) system in tuna processing in the Solomon Islands

Thank you for your letter received on 1 June 2010.

On behalf of the Massey University Human Ethics Committee: Southern B I am pleased to advise you that the ethics of your application are now approved. Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

Dr Karl Pajo, Chair
Massey University Human Ethics Committee: Southern B

cc Dr John Ruck
IFNHH
WELLINGTON

Prof Richard Archer, HoI
IFNHH
PN452

Dr Beatrice Dias-Wanigasekera
Senior Food Scientist
Risk Assessment (Microbiology)
Food Standards Australia & New Zealand
108 The Terrace
WELLINGTON

Massey University Human Ethics Committee
Accredited by the Health Research Council

Te Kunenga ki Pūrehuroa

Research Ethics Office, Massey University, Private Bag 11222, Palmerston North 4442, New Zealand
T +64 6 350 5573 +64 6 350 5575 F +64 6 350 5622
E humanethics@massey.ac.nz animalethics@massey.ac.nz gtc@massey.ac.nz
www.massey.ac.nz

Appendix II Letter to Chairman of Soltai Ltd Board seeking permission to conduct the study

Massey University
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Private Box 756
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New Zealand
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www.massey.ac.nz

Date:

Chairman
Soltai Fishing & Processing Company Ltd Board of Management
P.O Box 1
Noro
Western Province
Solomon Islands

Thru: General Manager

Dear Sir,

RE: PERMISSION TO CONDUCT A RESEARCH STUDY AT SOLTAI LTD COMPANY PREMISES

I am hereby submitting my letter of application seeking approval and permission from you to enable me to conduct the study at Soltai Fishing & Processing Company Limited.

Firstly, I wish to introduce myself to you. My name is Ernest Kolly from Isabel Province in the Solomon Islands. Currently I am studying at Massey University, Wellington Campus, for a Master of Health Science majoring in Environmental Health. In partial fulfilment for the Masters qualification, I am required to conduct a research study of my interest. As such, I have chosen to conduct a study on seafood safety and quality assurance with your company.

I have picked Soltai Fishing & Processing Company Limited as this is the only tuna processing company in the country. My interest is to work in partnership with the company to critically and confidentially evaluate the HACCP food safety management system in place and determine factors that could influence effective implementation of the food safety system and its feasibility in tuna industry in the context of the Solomon Islands

Given, the importance of exporting tuna loins to the EU and the fact the government is proposing to further invest in tuna industry in the country, the study will form a baseline framework on the application of the HACCP food safety system in tuna industry in general. The study will also help Soltai Ltd to determine factors which may impede or influence effective implementation of the HACCP food safety system and further improve to enhance seafood safety and quality assurance. The study will also help the

Competent Authority to evaluate its performance in conducting systemic monitoring (auditing) of the HACCP system in tuna industries and help in the development of a national framework that will enhance food safety and quality assurance and meet national and international standards.

The study will be sponsored by NZAID. As the study will involve collection of tuna samples for histamine and faecal coliform *(E.coli)* analysis, sampling of the food contact surfaces and swab sampling of factory workers hands, I request permission to take samples of tuna to test for histamine and faecal coliform (*E.coli*) at the Soltai Ltd laboratory. The study will also involve interviews of the Line Managers and Factory Workers. I therefore seek permission and approval to conduct interviews and a survey questionnaire with company employees who will be invited to take part in the study.

As the study is significant to the economic development of the country, I have been granted a research permit by the Solomon Islands Government to conduct the study (see attached). I have also been granted ethical clearance by the MHMS and obtained their endorsement to conduct the study in partnership with your company.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 10/12. If you have any concerns about the conduct of this research, please contact Dr Karl Pajo, Chair, Massey University Human Ethics Committee: Southern B, telephone 04 801 5799 x 6929, email humanethicsouthb@massey.ac.nz

Attached is a copy of my research proposal and relevant documents in support of my proposed study for your reference. Please do not hesitate to contact me or the above person for further clarification.

I am looking forward to your favourable consideration of my application.

Thank you very much,

Yours sincerely,

Ernest Kolly
Master of Health Science (Environmental Health) student
Institute of Food, Nutrition & Human Health
College of Sciences
Massey University
Wellington Campus
New Zealand
Email: e.kolly@massey.ac.nz

Appendix III Letter to General Manager NFD Ltd seeking permission to conduct the study

Massey University
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www.massey.ac.nz

Date:

General Manager
National Fisheries Developments Company Limited
P.O Box 717
Honiara
Solomon Islands

Dear Sir,

RE: PERMISSION TO CONDUCT A RESEARCH STUDY ON BOARD NFD LTD FISHING VESSELS

I am hereby submitting my application seeking approval and permission from you to enable me to conduct the study on board NFD fishing vessels.

As per my previous correspondences about my interest to conduct a study with NFD Ltd and Soltai Ltd with regards to seafood safety and quality assurance, this is the formal application seeking approval after ethical formalities and a research permit is granted by the university ethics committee and the Solomon Islands Government respectively.

My interest is to work with the companies to critically and confidentially evaluate the HACCP food safety management system in place and determine factors that could influence effective implementation of the food safety system and its applicability in tuna industry in the context of the Solomon Islands

Given, the importance of exporting tuna loins to the EU and the fact the government is proposing to further invest in tuna industry in the country, the study will form a baseline framework on the application of the HACCP food safety system in tuna industries in general. The study will also help NFD Ltd to determine factors which may impede or influence effective implementation of the HACCP system and further improve to enhance seafood safety and quality assurance. The study will also help the Competent Authority to evaluate its performance in conducting systemic monitoring (auditing) of the HACCP system in tuna industries and help in the development of a national framework that will enhance food safety and quality assurance and meet national and international standards.

The fact that NFD Ltd is the major supply of raw material (tuna) to Soltai Ltd, it is imperative that my study will involve your company fishing vessels. This will involve determining how the raw tuna is handled and stored in the fishing vessels as well as critiquing how the good operating procedures (GOP) are maintained on board the fishing vessels as per the pre-requisite of exporting tuna loins to the European Union.

The study will be sponsored by NZAID. As the study will involve collection of tuna samples for histamine and faecal coliform *(E.coli)* analysis, I request permission to take samples of tuna to test for histamine at the Soltai Ltd laboratory. The study will also involve interviews of the Chief Engineers and Captains on board the fishing vessels that are responsible for fish handling and maintenance of GOP on board the fishing vessels. I therefore seek permission and approval to conduct interviews and a survey questionnaire with company employees who will be invited to take part in the study.

As the study is significant to the economic development of the country, I have been granted a research permit by the Solomon Islands Government to conduct the study (see attached). I have also been given ethical clearance by the MHMS and obtained their endorsement to conduct the study in partnership with your company.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 10/12. If you have any concerns about the conduct of this research, please contact Dr Karl Pajo, Chair, Massey University Human Ethics Committee: Southern B, telephone 04 801 5799 x 6929, email humanethicsouthb@massey.ac.nz

Attached is a copy of my research proposal and relevant documents in support of my proposed study for your reference. Please do not hesitate to contact me or the person above for further clarification.

I am looking forward to your favourable consideration of my application.

Thank you very much,

Yours sincerely,

Ernest Kolly
Master of Health Science (Environmental Health) student
Institute of Food, Nutrition & Human Health
College of Sciences
Massey University
Wellington Campus
New Zealand

Appendix IV Letter to Permanent Secretary, Ministry of Education & Human Resources Development, Solomon Islands

Massey University
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12th March 2010.

Permanent Secretary
Ministry of Education & Human Resources Development
PO Box G28
Honiara
Solomon Islands

Attention: Chairman, Research Committee

Dear Sir,

Re: Application for a research permit

My name is Ernest Kolly from the Solomon Islands pursuing a Master of Health Science majoring in Environmental Health at Massey University of Wellington.

I am intending to conduct a research study in the Solomon Islands on seafood safety and quality assurance. My place of study will be at Noro, Western Province. I am intending to conduct my study with Soltai Fishing & Processing Company Limited and National Fisheries Developments Co Ltd. My tentative date for my data collection is in June/July 2010.

Prior to convening the study, it is a requirement under the Massey University ethical process that I have to submit my research proposal to the University Human Ethics Committee for approval. Subjective to the Massey University Human Ethics Committee approval, I will submit a formal request through Soltai Fishing & Processing Company Limited management and National Fisheries Development Company for their approval to conduct the study. Pending approval of my research proposal and application to the Massey University Human Ethics Committee, I am submitting my application seeking for a research permit as I am running against time. I am optimistic that my research proposal will be approved by the university human ethics committee by then.

Attached herewith is my filled research permit application form for your perusal and approval.

I am willing to further facilitate your office of other relevant documents if requested. Please feel free to contact me on my email address, e.kolly@massey.ac.nz or phone + 64 04 589 5188 or mobile, +64 4 02102528112

Your approval to my research application will be greatly appreciated

Thank you

Yours faithfully,

Ernest Kolly
Master of Health Science (Environmental Health) candidate
Institute of Food, Nutrition & Human Health
College of Sciences
Massey University
Wellington Campus
New Zealand

Appendix V Research permit from Ministry of Education, Solomon Islands

FORM – R.B

THE RESEARCH ACT 1982
(No. 9 of 1982)

RESEARCH PERMIT (EXTENSION)

Permission is hereby given to:

1. Name: **Ernest Kolly**
2. Country: **Solomon Islands**
3. To undertake research in (subjects): **The Seafood Safety & Quality Assurance**
4. Ward(s): **Noro**
5. Province(s): **Western**
6. Conditions:

   a. To undertake research only in the subject areas specified in 3 above.
   b. To undertake research only in the ward(s) and Province(s) specified in 4 and 5 above.
   c. To observe with respect at all times local customs and the way of life of people in the area in which the research work is carried out.
   d. You must not, at any time, take part in any political or missionary activities or local disputes.
   e. You must leave 4 copies of your final research report in English with the Solomon Islands Government Ministry responsible for research at your own expense.
   f. A research fee of *SBD300.00* and deposit sum of *SBD200.00* must be paid in full or the Research Permit will be cancelled. (See sec. 3 Subject. 7 of the Research Act).
   g. This permit is valid until ___**31/05/11**________provided all conditions are adhered to.
   h. No live species of plants and animals may be taken out of the country without approval from relevant authorities.
   i. A failure to observe the above conditions will result in automatic cancellation of this permit and the forfeit of your deposit.

Signed: ……………………………………………
Minister for Education and Human Resources Development

Date: 14/5/2010

Appendix VI Company (Soltai Ltd) joint agreement form

Joint agreement between Soltai Fishing & Processing Company Limited and Ernest Kolly (Researcher)

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www.massey.ac.nz

Research title: *'From boat to bowl'*- An exploratory study of the implementation of the Hazard Analysis Critical Control Point (HACCP) system in tuna processing in the Solomon Islands

I, Thomas Dorku, General Manager of Soltai Fishing & Processing Company Limited on behalf of the Soltai Board of Directors do make the following statements:

1. I have approved on behalf of the Board, for Ernest Kolly to conduct research in Soltai Ltd from 20th September to 16th October 2010;
2. That permission is given to Mr. Kolly to access HACCP related documents that are necessary for the successful conduct of the research.
3. That having fully co-operated, I expect them to provide views and opinions in context of food safety practices, some of which might be dissenting. I further state that neither I nor any management staff will actively seek dissenting views in the study for the purpose of incriminating and punishing staff
4. As an academic work, some of the data will be viewed by Mr.Kolly's supervisor and by the wider academic community in the form of formal publications. The Company will be given drafts of any publications or other outputs for comment.
5. The embargoing of the final Thesis, should it be necessary, is the sole prerogative of Massey University.

I, Ernest Kolly, researcher and student of Massey University at Wellington make the following statements:

1. I agree to conduct research at Soltai Ltd, Noro base, Western Province, Solomon Islands
2. That at all times, I will maintain a high standard of ethical behaviour during the course of my research
3. That I will respect the integrity and privacy of all the staff and workers
4. That the Human Resources Administration Manager, Mr. Asery Kukui will be my first point of contact for logistics and to the wider organisation
5. That all soft and hard copies of the documents will be returned to Soltai Ltd or electronically destroyed after the research
6. That a bound copy of the thesis will be provided to the company (Soltai Ltd) for reference

We hereby set our hands:

[signature]	[signature]
Mr. Thomas Dorku General Manager Soltai Fishing & Processing Company Ltd	Mr. Ernest Kolly Researcher
Date: 20-9-2010	Date: 20/9/10

Appendix VII Participants' Information sheet

Massey University
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PARTICIPANTS INFORMATION SHEET

Dear Sir/Madam,

I am a Solomon Islander studying at Massey University of Wellington, New Zealand. As part of my study towards a Master of Health Science majoring in Environmental Health, I wish to do research in areas of seafood safety and quality assurance. I therefore, would like to invite you to participate in a self administer quantitative survey questionnaires and a one on one interview. The participants have the right to accept or decline the invitation. This research has been assessed and approved by the Massey University Human Ethics Committee.

The purpose of the study is to determine knowledge, attitude and behaviour of the company employees on the implementation of the Hazard Analysis Critical Control Point (HACCP) food safety system in the tuna industry. The outcome of the study will not only fulfil my purpose for qualification but will also enhance food safety and quality assurance to protect consumers' health. More especially will contribute positively to the socio- economic developments of the Solomon Islands in terms of trading with the European Union.

The study will be divided in four phases as follows;

Phase one: Histamine control/monitoring on board the fishing vessels
This involves critiquing the HACCP system on board the fishing vessels. Time and temperature will be the critical determinants. Tuna samples to test for histamine (chemical) and *E.coli* (microbiological) at the landing site on every unloading trip of the fishing vessels will be conducted.

Phase two: Process monitoring in the factory
This involves collection of tuna samples during fish acceptance on daily basis on a 4 week period to test for histamine and *E.coli*. Swab samples will also be collected on food contact surfaces and food handlers to test for faecal contamination.

Phase three: Quantitative survey
Phase three will involve conducting a questionnaire survey of the engineers, managers and factory workers.

Phase four: Qualitative interview
Phase four will involve a one on one exploratory interview of the managers and factory workers. On the spot ethnographic observation in the factory to determine whether the local culture influences the implementation of the HACCP food safety system in place will also be conducted.

Since company employees will be involved in the study, it is a requirement of Massey University that due consideration to ethical principles and standards are adhered to. Therefore consent is sought for your participation in this study. Your participation includes that: your name/identity or personal background information provided will be treated as confidential and anonymous; your responses will be collected as aggregated data and could be used for quotation or reported as narratives; you have the right to verify or check the interview notes; you have the right to ask me for feedback on the results; you have the right to withdraw from the study up until the data analysis and if you choose to withdraw, any data collected from you will not be used in the study. The interview data gathered will be solely use for purposes of the study and will be safely stored in my personal external computer drive. At the conclusion of the study all laboratory tests results, quantitative survey and interview data materials will be destroyed.

The final results of this study will be published as thesis and can be accessed at the following places. This includes deposits of the thesis at the libraries of Massey University, National Library of the Solomon Islands or through academic journals.

If you agree to this request I would appreciate it very much if you could sign and date the consent form attached. The self administer questionnaire survey will be distributed personally to you on the first week of the study and will be grateful if you could return it to me upon you finish filling it. I would be most happy to conduct the interview at a time convenient to you.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 10/12. If you have any concerns about the conduct of this research, please contact Dr Karl Pajo, Chair, Massey University Human Ethics Committee: Southern B, telephone 04 801 5799 x 6929, email humanethicsouthb@massey.ac.nz
Should you have further queries regarding the study, please do not hesitate to contact me or any of my supervisors for further clarifications. My supervisors can be contacted on the following addresses;

Dr John Ruck
Senior Lecturer and Principal Supervisor
Institute of Food, Nutrition & Human Health
College of Science
Massey University of Wellington, **New Zealand**
Tel: 64 4 801 5799 ext 62142
Fax: 64 4 801 4994
Email: J.G.Ruck@massey.ac.nz

Dr Beatrice Dias-Wanigasekera
Senior Food Scientist & External Supervisor
Risk Assessment (Microbiology)
Food Standards Australia and New Zealand
8 Huyer Street, Gungahlin
Canberra, ACT
AUSTRALIA
Tel: 0061-2 6271-2698
Email: Beatrice.dias-wanigasekera@foodstandards.gov.au

Thank you

Yours faithfully,

Ernest Kolly
Institute of Food, Nutrition & Human Health
Massey University of Wellington
Email: e.kolly@massey.ac.nz

Appendix VIII Participants' consent form

INDIVIDUAL PARTICIPANT CONSENT FORM (ENGLISH & SOLOMON ISLANDS 'PIDGIN' VERSION)

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'From boat to bowl'-An exploratory study of the implementation of the Hazard Analysis Critical Control Point (HACCP) system in tuna processing in the Solomon Islands

PARTICIPANT CONSENT FORM - INDIVIDUAL

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time. I acknowledge that I may also withdraw from the study at any stage prior to final data analysis. *(Please tick the boxes if you agree with the statement)*

☐ I understand that I have been given sufficient information and have understood the purpose of the research project. *(Mi agree and understandim that mi been garem enough information long wanem nao main purpose blong study ia)*

☐ I understand that my name/identity or personal background information will be treated as confidential and anonymous. *(Mi understandim that name blong mi bae hem no usim long disfala study)*

☐ I understand that my interview responses will be collected and could be used for quotations or reported as narratives. *(Mi undersandim that oleketa responses blong mi long interview bae hem use long writem up thesis work ia)*

☐ I understand that I have the right not to answer any interview questions. *(Mi understandim that mi garem right fo no anserem olketa interview if mi no agree?*

☐ I understand that I have the right to check or verify my interview transcriptions. (Mi understandim that mi garem right fo chekem olketa ineterview transcription mi talem)

☐ I understand that I have the right to ask for feedback on the results. *(Mi understandim that mi save askem feedback long olketa results blong data long study ia)*

☐ I understand and agree that the interview will be sound/tape recorded *(Mi understandim* an *agree that bae interview blong mi hem recorded)*

☐ I understand that the data collected will be solely used for study purposes.*(Mi understandim that data collected by hem use fo study purpose nomoa)*

☐ I understand that the data collected will be safely stored and all interview data and interview materials will destroyed at the conclusion of the study. *(Mi undrstandim that olketa data collected and interview mi duim bae olketa destroyed long finish blong study ia)*.

☐ I agree to participate in this study under the conditions set out in the information sheet *(Mi agree fo take part long disfala study followem wanem hem set out long disfala informeson sheet ia)*

Signature: .... **Date:** ....

Full Name - printed ....

Appendix IX Survey Questionnaire

QUANTITATIVE SURVEY QUESTIONNAIRE (ENGLISH & 'PIDGIN VERSION) *(survey questionnaire to determine knowledge, attitude and behaviour of the HACCP food safety system).*

Research title: *'From boat to bowl'*- An exploratory study of the implementation of the Hazard Analysis Critical Control Point (HACCP) system in tuna processing in the Solomon Islands

Introduction:

Before you answer the survey questionnaire, please read the questions carefully. I would be most grateful if you can spare me few of your time to answer the survey questionnaire. If you cannot write in English, you can write your answers in "Pidgin' and I will transcribe, transform and translate the answers into English. I will collect the survey questionnaires from you once completed. Your willingness to participate in the study is very much appreciated.

Part A

1. **Demographic data** (tick or circle whichever is the appropriate answer)

1.1 Participant No: SOL/10/0

1.2 Designation/position

1.3 Gender:

- Male
- Female

1.4 Number of years working in the company Specify if known:

- 5 yrs or fewer
- 6-15 yrs
- 16-25 yrs
- 26 yrs or more

1.5 Nationality:

- Solomon Islander
- Others (others include non-Solomon Islanders).

1.6 Educational background:

- Primary (grade1-6)
- Secondary (Form 1-7)
- Vocational
- Tertiary
    - College
    - University

None (not attending formal school)

2. KNOWLEDGE (*tick or circle only one answer*)

2.1 Familiarity

2.1.1 What do you understand by the term 'food hazard'?*(Wat nao iu save abaot disfala tem 'food hazard'?)*

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

2.1.2 What do you understand by the term 'food risk'?*(Wat nao iu save long disfala tem 'food risk'?)*

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

2.1.3 Are you familiar with the term HACCP? Yes/No
(Waswe iu save long disfala tem HACCP ia?)

2.1.4 What do you think HACCP stands for or means? *(Wat nao oketa leta HACCP ia hem minim?)*

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

2.1.5 Are you familiar with the seven principles of HACCP? (Yes/No), if yes, list them: *(Iu save tu long olketa seven fala impoten pricipol blong HACCP? If yes, iu save listim daon*

1 ....
2 ....
3 ....
4 ....
5 ....
6 ....
7 ....

2.2.0 Awareness

2.2.1 Have you attended training in HACCP food safety management (Yes/No), if no go on to Q2.2.3.*Waswe iu attendem eni tranin long HACCP tu? If nomoa iu go ansarem Q2.2.3*

2.2.2 If yes, when was the last time you attended HACCP food safety training? and proceed to Q2.2.5 .(*if yes, wat taem nao las taem iu attendem kos long HACCP?) n iu ansarem Q2.2.5*

- Less than 6 months
- Last year
- last 2 years
- last 3 years

2.2.3 If no, have you attended any training in basic food hygiene (Yes/No) if yes, go on to Q2.2.4 & Q2.2.5 (*waswe iu attedem eni kos long food hygiene tu?) if yes, iu anserem Q2.2.4*

2.2.4 If yes, when was the last time you attended food hygiene training? *(If yes, wat taem nao las taem iu attendem kos long food hygiene?)*

- Less than 6 months
- Last year
- Last 2 years
- Last 3 years

2.2.5 Who conducted the training? (*Hu nao karem aot kos ia?)*

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

2.2.6 When have you first heard or read about the HACCP concept? *(Wat taem nao iu fes herem disfala wod HACCP ia?)*

a) Now
b) last 6 months
c) Last year
d) Last 2 years
e) Last 3 years

2.2.7 Do you think there is adequate information/awareness on the importance of HACCP food safety system in place? (Yes/No) (*Waswe iu ting infomesin abaot impotan blong HACCP ia hem inaf?)*

2.2.8 If no, who do you think should be responsible to pass on information/awareness about HACCP food safety to industries? *(if nomoa, hu nao u tingim shud karem aot waka olsem?)*

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

2.3 Comprehension

2.3.1 What could you do to implement the HACCP system in your workplace?
(Hao nao iu save karem aot disfala HACCP system ia long waka ples blong iu?)

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

3. ATTITUDE

3.1 Agreement

3.1.1 To what extent do you agree with the HACCP concepts/guidelines? (*Hao strong nao agriment blong iu long HACCP system ia)*

1. Fully
2. Partially
3. Not at all

3.2 Commitment

3.2.1 How often do you comply with the HACCP systems (*Hao many taem nao iu save falom nao disfala HACCP system ia?*

- All the time
- Sometimes
- Never

3.2.2 What do you think are the major barriers to the implementation of the HACCP food safety management system in your company? Please explain
Wat nao iu tingim olsem big fala samting wea mekem disfala HACCP hem no waka gut long kampani?

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

3.2.3 What do you think are the major positive ways of implementing the HACCP food safety system in your company? Please explain
Wat nao iu tingim olsem ol gud fala samtin wea mekem disfala HACCP hem waka gut long kampani?

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

4. BEHAVIOUR

4.1 Adoption

4.1.1 How does your understanding of the HACCP guidelines affect your behaviour in the workplace? Please give examples *(Hao nao save blong iu abatem disfala HACCP hem afectem wea blong iu long ples wea iu waka?) iu save givim exampol*

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

4.1.2 Before you heard about the HACCP guidelines, did you do anything differently in the workplace? If yes, briefly explain *(Taem iu no herem disfala HACCP, waswe iu duim samfala samting hem difren long ples blong wok blong iu?) iu save givim exampol*

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

4.2 Adherence

4.2.1 Do you think it will be easy to, sustain the implementation of the HACCP guidelines in your line of work? Please provide the reason for your answer? *(Waswe, iu ting hem isi for karem aot nao disfala HACPP ia long wok ples?)iu save givim exampol*

1.1 Yes
1.2 No

4.2.2 What do you think should be done to improve the implementation of HACCP food safety system in your company? *Wat nao iu tingim fo duim fo improvem nao hao fo karem aot disfala HACCP long kampani?*

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

4.2.3 What is the main drive behind your company in implementing the HACCP food safety system? *Wat nao big fala samting wea hem mekem iu fala fo karem aot and falom nao disfala HACCP sistim ia?*

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

5.0 Cultural influences

5.1.1 Do you think the local culture does have a lot of influences on the implementation of the HACCP food safety system? If yes or no, briefly explain the reason for your answer. *Waswe, iu tingim dat kastom blong iumi hemi garem staka samting long karem out gutfala disfala HACCP long waka ples?Iu save explenim ansa blong iu*

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

5.1.2 How can the influence of the local culture be overcome? *Iu save tingim oketa wei wea iu ting save stopem nao lokol kastom blong iumi fo no affectem nao disfala samting oketa kolem HACCP?*

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

PART B: ATTITUDE/PERCEPTION CHECKLIST

Brief:

This summary checklist is prepared purposely to determine participant's attitude and perception about the implementation of the HACCP system (*Please tick only **one** box of your preference).*

***Key**: 1-Strongly disagree 2-Disagree 3-Neither agrees nor disagrees 4- Agree 5-Strongly agree*

Statement	**1**	**2**	**3**	**4**	**5**
The company is responsible towards delivering safe fish/fish products to its consumers					
Top managers are fully committed to ensure the safety of fish/fish products					
Staff training on food safety is important					
Unsafe food handling practices can increase the risk of our fish/fish products					
The company is able to respond to and satisfy customer and market requirements for food safety					
Operators are motivated to ensure the safety of the fish/fish products					
HACCP implementation must be a mandatory requirement for the fish industry in the Solomon Islands					
I have access to all information					

required about food safety management					
Inspections and audits of the food safety management system provide opportunities for improvement					
I am well informed about current laws/regulations governing food safety					
The company has qualified personnel to effectively manage the safety of its fish/fish products					
There is a need for a culture change in staff to better manage food safety					
The company has received pressure from stakeholders to implement a food safety management system					
I am well informed about food safety and how to manage it					
The management of food safety is a burden to the company					
There is close collaboration between the fish industry and the government to promote food safety management programmes					
The company delays to solve food safety incidents					
A food safety management system is difficult to apply in a company of our size					
There is risk that someone can contract food poisoning from our fish/fish products					
There is no real incentive for having a HACCP/food safety management systems					
Food safety is not really a business priority					

Source: adapted from (Ramnauth, et al., 2008) and (Bas, et al., 2007).

PART C: SURVEY QUESTIONNAIRE SPECIFIC FOR THE FISHING VESSELS ONLY

Maintenance of GMP's onboard fishing vessels.

1. Are all the fishermen aware of the HACCP system on board the fishing vessel? (yes/No), if no, why? please briefly explain

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

2. How often do you clean/wash the vessel while out fishing?

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....

3. What type of chemicals/detergents do you normally use to clean/wash the vessel?

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....
....

4. Where do you store your detergents/chemicals on the vessel?

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

5. During unloading where do you get your source of water to clean the vessel?

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

6. What procedures do you put in place to clean/wash the vessel during and after unloading fish?

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

7. Where do you get your raw (refrigerated) sea water to make your brine from?

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

8. How often do you change your brine?

………
………
………
………
………

9. Who monitors the effective implementation of the GOP's onboard the fishing vessel? And how often do they conduct audit of your vessel?

………
………
………
………
………

10. What are the major barriers to maintaining HACCP system on board the fishing vessel? List and please explain?

………
………
………
………
………

Appendix X Cue questions for the qualitative exploratory (one on one *talanoa*) interview

CUE QUESTIONS FOR THE QUALITATIVE EXPLORATORY INTERVIEW (ENGLISH & SI 'PIDGIN' VERSION)

The one on one Talanoa style exploratory interview will follow the outline below. These are only cue questions, reminders of the general direction I would like the conversation to go. However, it is appreciated, as with most exploratory interviews, the conversation may take many different turns, and the interviewer will often ad lib questions to keep the dialogue alive. The questions will not be delivered as formally as they appear below.

"Welcome and good day to you. Having filled in the survey questionnaire and read the information sheet you will be aware of the overall purpose of this study. In this short interview, I want to explore with you your experience of food preparation in your home village/town, where traditional approaches have been passed from generation to generation. I am interested in your opinion on your local culture (kastom) and any influence it may have on the implementation of the HACCP food safety system in the factory, where you work. This short interview will be recorded and I will transcribe, transform and translate the interview into English for you to verify. If you agree to the interview, we shall start now".

"Let's begin with your recollection of growing up in your home and your memory of being taught by your father or mother or other members of your family and village/town. Who was responsible for food preparation….did it vary with type of food….how were foods prepared…. is there any spiritual significance…?" *(Iumi tufala ting bael long taem wea u grow up long hom, who nao hem save mekem preparem kaikai blong iu, an, hao iu prepare kaikai blong iu? Hem differen long evri kinf kaikai or hao?*

1. "Are these practices continued by you today?" *(Waswe, olketa wea ia hemi go het distaem?*

If not already commented on, then draw from participant, ways recent practices in food preparation may have influenced food preparation in the home/village/town situation. In general terms not necessarily just HACCP principles.

2. "Are you aware of any traditional food preparation which has been influenced by more recent, shall we say western, ways to prepare food?" *(waswe iu save long eni old fala wei fo preparem kaikai wea olketa niu fala wei hem mekem eni big fala diffrens?)*
3. "Bringing those experiences of traditional food preparation into the factory situation, how did you feel when introduced to a more formal process, which is controlled by HACCP principles?" *(Hao nao u fil taem iu first kam waka long ples wea olketa karem aot HACCP?)*

4. “Did you find there was any conflict between traditional approaches and what happens in the factory….any resistance….anything you found strange, or were uncomfortable with….did you find it hard to adapt….or perhaps did you find it easy or complementary to traditional practices.…? (waswe u findem eni ting wea hemi *big fala diffrens wea iu lukim long wei wea iumi preparem kaikai long hom en long factory)*
5. Do you think the local culture does have a lot of influence in the implementation of the stringent HACCP food safety system in the factory? *(ok, so u ting se dat kastom blong iumi hem garem staka influence tumas long karem aot HACCP food system ia?*
6. In what ways do you think the local culture is a barrier to implementing the stringent HACCP food safety system? (ok*, long wat kaen wei nao u ting se kastom blong iumi hem nao blockem nao fo karem aot disfala HACCP food safety system ia?*
7. What other ways do you think should be done to overcome the barrier? *(so wat kaen wei nao u ting u should karem aot fo overcome nao olketa barrier ia?)*
8. “Were you able to embrace the new approaches used by HACCP and perhaps even apply them to your home situation?” (waswe iu save usim and duim olketa samting iu lanem abaot HACCP long hom?).
9. “Have you anything to say about how new workers may be introduced to the food processing in the factory which would help them assimilate the traditional with current practices?” (U garem eni ting fo talem oketa niu waka man wea u ting might helpem olketa fo putim together kastom idea en knowledge wetem olketa new wea fo duim things?) hao nao olketa niu waka man, wea niu long factory en niu long HACCP olketa bin guided fo falom olketa HACCP wei ia? Wat nao chain of command?
10. Do you have any general comment to make about the importance of HACCP food safety system in the factory and in the local context? *(waswe iu garem en ting ting nomoa wea like sharem long importen blong HACCP long factory en long hom blong iumi?*

Conclusion: I’d like to take this opportunity to thank you very much for your time and answers to the interview. It has been great having you as a participant to this study. Thank you very much.

Appendix XI: Summary records of the review of GMPs on board fishing vessels

SUMMARY OF THE MEDIAN TEMPERATURE ON BOARD SOLOMON EMERALD											
Wells	7/09/2010	8/09/2010	9/09/2010	10/09/2010	11/09/2010	12/09/2010	13/09/2010	14/09/2010	15/09/2010	16/09/2010	17/09/2010
Port 1	**-1.35**	-0.6	-0.65	-2.2	-1.8	-10.5	-16.35	-16.25	-15.5	-15.65	-16.9
Port 2	**-16.25**	-16.65	-16.45	-14.05	0.3	0.45	-0.4	-0.45	-4.85	-12.35	-16.9
Port 3	**-0.2**	-12.3	-18.25	-17.5	-17.2	-15.55	-15.2	-15.85	-17.95	-22.7	-23.7
Port 4	**-14.35**	-13.4	-13.3	-14.75	-14.15	-14.5	-14.35	-15.7	-14.8	-13.75	-14.6
Port 5	**-16.75**	-15.3	-15.2	-16.3	-16.5	-16	-16.05	-16.35	-16.25	-15.7	-16.5
STB 1	**5.2**	7.45	6.4	-1.65	-0.1	-6.6	-13.05	-16.3	-16.15	-12.75	-14.1
STB 2	**-14.2**	-12.45	-11	-8.05	-14.05	-4.85	-6.8	-6.15	-4.75	-12.3	-18.9
STB 3	**-0.6**	-1.5	-1.2	-9.25	-16.5	-15.55	-15.6	-16.4	-17.75	-20.75	-21.9
STB 4	**-15.6**	-16.35	-16.3	-16.4	-16.5	-15.1	-15	-16.7	-17.35	-17.75	-18.5
STB 5	**-14.9**	-15.1	-15.7	-15.1	-15.25	-14.05	-13.5	-15.05	-15.6	-15.2	-15.1

SUMMARY OF THE MEDIAN TEMPERATURE ON BOARD SOLOMON PEARL														
Wells	16/9/10	17/9/10	18/9/10	19/9/10	20/9/10	21/9/10	22/9/10	23/9/10	24/9/10	25/9/10	26/9/10	27/9/10	28/9/10	29/9/10
Port 1	-12.05	-13.6	-15.65	-17.2	-15.85	-14.6	-14.6	-14.6	-15	-15.55	-15.95	-16.25	-15.95	-15.55
Port 2	-10.1	-14.8	-18.25	-21.95	-22.05	7.65	-1.25	-1.8	-1.85	-1.25	-1.7	-3.9	-0.15	-0.05
Port 3	-0.35	-0.05	0.2	-0.65	-0.5	-0.85	-0.7	-0.6	-0.7	-8.75	-16.05	-18.1	-20.45	-24.9
Port 4	7.15	-1.35	-0.7	-0.8	-0.05	-8.35	-17.6	-17.4	-17.55	-18.8	-16.35	-20.6	-20	-15.8
Port 5	0.15	-0.35	-9.7	-13.4	-15	-14.85	-14.7	-14.95	-15.2	-14.8	-14.3	-14.1	-16.35	-15.9
STB 1	-12.2	-12.95	-14	-14.85	-15.85	-16	-16.35	-16.6	-16.25	-16.45	-16.5	-16.65	-16.05	-15.55
STB 2	-8.6	-12.55	-14.8	-16.15	-16.95	9.6	-1	1.35	-1.35	0.95	-1.15	-1.35	-1.35	-0.95
STB 3	-0.7	0.55	3	-0.65	-0.8	-0.9	-1.05	-1.1	-1.1	-0.4	-6.2	-12.55	-15.35	-14.4

Appendix XII Microbiological analysis results

National Public Health Laboratory (NPHL)
P.O. Box 349, Honiara, Solomon Islands.
Telephone : (677)38871 Fax: (677) 30644

Test Report No.: MTR - 121043

Date of Issue : 16/12/10
Page : 1/5

TEST REPORT

cc : Laboratory Head, NPHL
cc : Director, EHD
cc : Microbiology Dept., NPHL

Customer: Ernest Kolly,
New Zealand.

Sampler: Ernest Kolly,
Researcher.

National Public Health Laboratory (NPHL)
Prince Philip Highway
Kukum
Honiara
Solomon Islands

Description of items : 12 tuna samples collected by the customer for research purposes from the Soltai Fishing & Processing Company processing line on 21.9.10 (4 samples), 22.9.10 (4 samples), 23.9.10 (4 samples).

Customer Identification : EK - NZ
Packaging : plastic seal-wrapped.
Receiving date : not noted
Analysis date : 15/11/10

Product code: n/a

Microbiology Results

Sample no.	Item/s tested	Results	
		Colony count at 30°C (*microorganisms per gram*)	*E. coli* colony count at 44°C (β-glucuronidase-positive *E. coli* per gram)
1	Site 1 Fish Acceptance (YFS1.8-3.4kg) - frozen tuna	3.9×10^3	<1
2	Site 2 Prior to 1st cleaning (YFS1.8-3.4kg) - cooked fish (L3)	<10	<1
3	Site 3 Loin cleaning (YFS1.8-3.4kg) - cooked tuna loins (L3)	3.3×10^3	<1
4	Site 4 Loin packing (L3) (YFS1.8-3.4kg) - cooked tuna loins	8.4×10^3	<1
5	Site 1 Fish Acceptance (YFS1.8-3.4kg) - frozen tuna	3.4×10^3	<1
6	Site 2 Prior to 1st cleaning (YFS1.8-3.4kg) - cooked fish (L2)	1.7×10^3 (estimated)	<1
7	Site 3 Loin cleaning (YFS1.8-3.4kg) - cooked tuna loins (L2)	2.2×10^4 (estimated)	<1
8	Site 4 Loin packing (L2) (YFS1.8-3.4kg) - cooked tuna loins	7.3×10^3	<1
9	Site 1 Fish Acceptance (SJS1.8-3.4kg) - frozen tuna	1.7×10^2	<1
10	Site 2 Prior to 1st cleaning (YFS1.8-3.4kg) - cooked fish (L1)	1.4×10^3	<1
11	Site 3 Loin cleaning (YFS1.8-3.4kg) - cooked tuna loins (L1)	1.3×10^4	<1
12	Site 4 Loin packing (L1) (YFS1.8-3.4kg) - cooked tuna loins	2.0×10^4	<1

Comments

Three frozen tuna, three cooked fish, and 6 cooked tuna loins were despatched on 24/9/10 from Soltai and sent to the NPHL for analysis. The customer requested total plate counts and *E. coli* counts on the samples.

For the analysis requested, the NPHL used method ISO 4833:2003 for Colony counts at 30°C and ISO 16649-2:2001 for Colony count at 44°C for β-glucuronidase-positive *E. coli*.

For the enumeration of the Colony counts at 30°C, ISO 7218:2007 was referred to for the methods of calculation.
Thus the counts above referred to as 'estimated' was because one plate had a low count (< 10 colonies).

In addition, the results for the *E. coli* colony counts (<1 blue CFU) is taken from ISO 16649-2:2001 where the plates do not contain any typical blue colonies on TBX media.

Note: Stomacher used for maceration.

Analyst ....
K. E. Irofufuli,
Laboratory Analyst (Microbiology)

Approved by ....
D. Manongi,
Supervising Head,NPHL

National Public Health Laboratory (NPHL)
P.O. Box 349, Honiara, Solomon Islands.
Telephone : (677)38871 Fax: (677) 30644

Test Report No.: MTR - 121043

Date of Issue : 16/12/10
Page : 2/5

TEST REPORT

cc : Laboratory Head, NPHL
cc : Director, EHD
cc : Microbiology Dept., NPHL

Customer: Ernest Kolly, New Zealand.	National Public Health Laboratory (NPHL) Prince Philip Highway Kukum Honiara Solomon Islands
Sampler: Ernest Kolly, Researcher.	

Description of items : 22 tuna samples collected by the customer for research purposes from the Soltai Fishing & Processing Company processing line on 27.9.10 (9 Fish landing + 4 Fish processing samples), 28.9.10 (4 samples), 29.9.10 (5 samples). The first 12 samples were then analysed i.e. 27.9.10 Fish landing (9 samples) & 27.9.10 Fish Processing (3 samples).
Customer Identification : EK - NZ
Packaging : plastic seal-wrapped.
Receiving date : not noted
Analysis date : 16/11/10
Product code: n/a

Microbiology Results

Sample no.	Item/s tested	Results	
		Colony count at 30°C *(microorganisms per gram)*	*E. coli* colony count at 44°C (β-glucuronidase-positive *E. coli* per gram)
1	**27.9.10** Sample 1 Fish Landing (YFM6kg) - frozen tuna in brine	7.1×10^2	<1
2	Sample 2 Fish Landing (YFM6kg)	2.7×10^3	<1
3	Sample 3 Fish Landing (YFM6kg)	5.8×10^3	<1
4	Sample 4 Fish Landing (YFM6kg)	5.4×10^2	<1
5	Sample 5 Fish Landing (SJM6kg)	9.2×10^2	<1
6	Sample 6 Fish Landing (YFM6kg)	2.3×10^2	<1
7	Sample 7 Fish Landing (SJS3.4kg)	3.6×10^3 (estimated)	<1
8	Sample 8 Fish Landing (SJS3.4kg)	3.1×10^2	<1
9	Sample 9 Fish Landing (SJS3.4kg)	7.7×10^2	<1
10	**27.9.10** Site 1 Fish Acceptance (YFS1.8-3.4kg) - frozen tuna	7.9×10^3	<1
11	Site 2 Prior to 1st cleaning (YFS1.8-3.4kg) - cooked fish (L3)	2.2×10^2	<1
12	Site 3 Loin cleaning (YFS1.8-3.4kg) - cooked tuna loins (L3)	1.2×10^3	<1

Comments

22 tuna samples were despatched on 30/9/10 from Soltai and sent to the NPHL for analysis. The first 12 of the tuna samples were then analysed for total plate counts and *E. coli* counts.

For the analysis requested, the NPHL used method ISO 4833:2003 for Colony counts at 30°C and ISO 16649-2:2001 for Colony count at 44°C for β-glucuronidase-positive *E. coli*.

For the enumeration of the Colony counts at 30°C, ISO 7218:2007 was referred to for the methods of calculation. Thus the counts above referred to as 'estimated' was because one plate had a low count (< 10 colonies).

In addition, the results for the *E. coli* colony counts (<1 blue CFU) is taken from ISO 16649-2:2001 where the plates do not contain any typical blue colonies on TBX media.

Note: Stomacher used for maceration.

Analyst ....
K. E. Irofufuli,
Laboratory Analyst (Microbiology)

Approved by ....
D. Manongi,
Supervising Head, NPHL

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Test Report No.: MTR - 121043

Date of Issue : 16/12/10
Page : 3/5

TEST REPORT

cc : Laboratory Head, NPHL
cc : Director, EHD
cc : Microbiology Dept., NPHL

Customer: Ernest Kolly, New Zealand.	National Public Health Laboratory (NPHL) Prince Philip Highway Kukum Honiara Solomon Islands
Sampler: Ernest Kolly, Researcher.	

Description of items : 22 tuna samples collected by the customer for research purposes from the Soltai Fishing & Processing Company processing line on 27.9.10 (9 Fish landing + 4 Fish processing samples), 28.9.10 (4 samples), 29.9.10 (5 samples). The remaining 10 samples were analysed i.e. 27.9.10 Fish Processing (1 sample), 28.9.10 (4 samples) & 29.9.10 (5 samples).
Customer Identification : EK - NZ
Packaging : plastic seal-wrapped.
Receiving date : not noted
Analysis date : 17/11/10

Product code: n/a

Microbiology Results

Sample no.	Item/s tested	Results	
		Colony count at 30°C (microorganisms per gram)	*E. coli* colony count at 44°C (β-glucuronidase-positive *E. coli* per gram)
1	**27.9.10** Site 4 Loin packing (L3) (YFS1.8-3.4kg) - cooked tuna loins	8.3×10^3	<1
2	**28.9.10** Site 1 Fish Acceptance (YFS3.4kg) - frozen tuna	1.4×10^3	<1
3	Site 2 Prior to 1st cleaning (YFS1.8-3.4kg) - cooked fish (L2)	3.1×10^2	<1
4	Site 3 Loin cleaning (YFS1.8-3.4kg) - cooked tuna loins (L2)	9.5×10^3	<1
5	Site 4 Loin packing (L2) (YFS1.8-3.4kg) - cooked tuna loins	4.1×10^3	<1
6	**29.9.10** Site 1 Fish Acceptance (YFL20kg) - frozen tuna	1.5×10^3	<1
7	Site 2 Prior to 1st cleaning (YFM3.4-10kg) - cooked fish (L1)	2.2×10^2 (estimated)	<1
8	Site 3 Loin cleaning (YFM3.4-10kg) - cooked tuna loins (L1)	7.2×10^3	<1
9	Site 4 Loin packing (L1) (YFS3.4-10kg) - cooked tuna loins	7.1×10^3	<1
10	Site 4(b) Tumor in cooked tuna loins (YFS3.4-10kg) (L2)	3.4×10^4	<1

Comments

22 tuna samples were despatched from Soltai on 30/9/10 and sent to the NPHL for analysis. The first twelve samples were analysed on 16/11/10 and the results shown on page 2 of the report. The remaining 10 tuna samples were also analysed and are shown on page 3 of this report.

For the analysis requested, the NPHL used method ISO 4833:2003 for Colony counts at 30°C and ISO 16649-2:2001 for Colony count at 44°C for β-glucuronidase-positive *E. coli.*

For the enumeration of the Colony counts at 30°C, ISO 7218:2007 was referred to for the methods of calculation. Thus the count above referred to as 'estimated' was because one plate had a low count (< 10 colonies).

In addition, the results for the *E. coli* colony counts (<1 blue CFU) is taken from ISO 16649-2:2001 where the plates do not contain any typical blue colonies on TBX media.

Note: Stomacher used for maceration.

Analyst ....
K. E. Irofufuli,
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Approved by ....
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Test Report No.: MTR - 121043

Date of Issue : 16/12/10
Page : 4/5

TEST REPORT

cc : Laboratory Head, NPHL
cc : Director, EHD
cc : Microbiology Dept., NPHL

Customer: Ernest Kolly, New Zealand.	National Public Health Laboratory (NPHL) Prince Philip Highway Kukum Honiara Solomon Islands
Sampler: Ernest Kolly, Researcher.	

Description of items : 21 tuna samples were collected by the customer for research purposes from the Soltai Fishing & Processing Company processing line on 01.10.10 (9 samples), 04.10.10 (4 samples), 05.10.10 (4 samples), 06.10.10 (4 samples). All samples were analysed over 4 days. The first eight results of 01.10.10 are contained in this report.

Customer Identification : EK - NZ
Packaging : plastic seal-wrapped.
Receiving date : not noted
Analysis date : 17/11/10 (first two samples), 2/12/10 (next 6 samples)   Product code: n/a

Microbiology Results

Sample no.	Item/s tested	Results: Colony count at 30°C (microorganisms per gram)	Results: *E. coli* colony count at 44°C (β-glucuronidase-positive *E. coli* per gram)
1	Sample 1 Fish Landing (YFM6kg) - Frozen tuna in brine	2.2×10^2 (estimated)	<1
2	Sample 2 Fish Landing (SJL6kg)	<4	<1
3	Sample 3 Fish Landing (SJS3.4kg)	1.1×10^3	<1
4	Sample 4 Fish Landing (SJS3.4kg)	7.1×10^2	<1
5	Sample 5 Fish Landing (SJS3.4kg)	<1	<1
6	Sample 6 Fish Landing (YFS3.4kg)	<1	<1
7	Sample 7 Fish Landing (YFS3.4kg)	1.6×10^2	<1
8	Sample 8 Fish Landing (YFM6kg)	5.6×10^3	<1

Comments

21 tuna samples were despatched from Soltai on 7/10/10 and sent to the NPHL for analysis. Eight results are shown above.

For the analysis requested, the NPHL used method ISO 4833:2003 for Colony counts at 30°C and ISO 16649-2:2001 for Colony count at 44°C for β-glucuronidase-positive *E. coli*.

For the enumeration of the Colony counts at 30°C, ISO 7218:2007 was referred to for the methods of calculation. Thus the count above referred to as 'estimated' was because one plate had a low count (<10 colonies). In addition, sample 2 (<4 colonies) is reported as "microorganisms are present but less than 4 per gram". Also, samples 5 & 6 results (<1) are reported as "less than 1 microorganisms per gram".

In addition, the results for the *E. coli* colony counts (<1 blue CFU) is taken from ISO 16649-2:2001 where the plates do not contain any typical blue colonies on TBX media.

Note: Samples 1-2 were macerated using the stomacher while samples 3-8 were macerated using 3 blenders. Two supplied by customer, one by the NPHL.

Analyst ....
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Test Report No.: MTR - 121043

Date of Issue : 16/12/10
Page : 5/5

TEST REPORT

cc : Laboratory Head, NPHL
cc : Director, EHD
cc : Microbiology Dept., NPHL

Customer: Ernest Kolly, New Zealand.

Sampler: Ernest Kolly, Researcher.

National Public Health Laboratory (NPHL)
Prince Philip Highway
Kukum
Honiara
Solomon Islands

Description of items : 21 tuna samples were collected by the customer for research purposes from the Soltai Fishing & Processing Company processing line on 01/10/10 (9 samples), 04/10/10 (4 samples), 05/10/10 (4 samples), 06/10/10 (4 samples). All samples were analysed over 4 days. The remaining 13 of the 21 samples were analysed in two groups, three days apart.
Customer Identification : EK - NZ Product code: n/a
Packaging : plastic seal-wrapped.
Receiving date : not noted
Analysis date : 3/12/10 (Sample 9: 1/10/10; Sites 1-4: 4/10/10, Site 1: 5/10/10) & 6/12/10 (Sites 2-4: 5/10/10; Sites 1-4: 6/10/10)

Microbiology Results

Sample no.	Item/s tested	Results	
		Colony count at 30°C (*microorganisms per gram*)	Coliform colony count at 30°C (coliforms per gram)
1	**01.10.10** Sample 9 Fish Landing (YFM6kg)	1.6×10^4	<1
2	**04.10.10** Site 1 Fish Acceptance (SJM1.8-3.4kg) - frozen tuna	1.7×10^2	<1
3	Site 2 Prior to 1st cleaning (SJM1.8-3.4kg) - cooked fish (L3)	<1	<1
4	Site 3 Loin cleaning (SJM1.8-3.4kg) - cooked tuna loins (L3)	8.3×10^3	<1
5	Site 4 Loin packing (L3) (SJM1.8-3.4kg) - cooked tuna loins	4.5×10^4	<1
6	**05.10.10** Site 1 Fish Acceptance (SJM1.8-3.4kg) - frozen tuna	1.2×10^3	<1
7	Site 2 Prior to 1st cleaning (SJM1.8-3.4kg)1.8-3.4kg) - cooked fish (L2)	8.1×10^2	<1
8	Site 3 Loin cleaning (SJM1.8-3.4kg)1.8-3.4kg) - cooked tuna loins (L2)	2.6×10^4	<1
9	Site 4 Loin packing (L2) (SJM1.8-3.4kg)1.8-3.4kg) - cooked tuna loins	1.6×10^4	<1
10	**06.10.10** Site 1 Fish Acceptance (SJS1.8-3.4kg) - frozen tuna	1.7×10^2	<1
11	Site 2 Prior to 1st cleaning (YFS1.8-3.4kg) - cooked fish (L1)	2.3×10^2	<1
12	Site 3 Loin cleaning (YFS1.8-3.4kg) - cooked tuna loins (L1)	6.3×10^3	<1
13	Site 4 Loin packing (L1) (YFS1.8-3.4kg) - cooked tuna loins	1.0×10^4	9.1×10^1

Comments

21 tuna samples were despatched from Soltai on 7/10/10 and sent to the NPHL for analysis. The remaining 13 results are shown above.

For the analysis requested, the NPHL used method ISO 4833:2003 for Colony counts at 30°C and BS ISO 4832:2006 for Coliform counts at 30°C. The standard BS ISO 4832:2006 was given by the customer.

For the expression of results, ISO 7218:2007 was referred to for the methods of calculation.
Thus, sample 3 result (<1) is reported as "less than 1 microorganisms per gram".

In addition, the results for the Coliform colony counts (<1 characteristic colony) is where the plates do not contain any typical colonies on VRBL media or atypical colonies on VRBL were confirmed to be non-colifoms in BGLB (ISO 7218:2007 & BS ISO 4832:2006).

Note 1: All 13 samples above were macerated using blenders.
Note 2: The change of method ISO 16649-2:2001 was due to insufficient TBX to continue with the method; and the choice of method BS ISO 4832:2006 was due to the availability of the required media listed.

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