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Risk assessment of vacuum-packed pouched tuna chunks during industrial processing using ISO 22000 and HACCP systems

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Abstract

Risk analysis was conducted during processing of Vacuum-Packed Pouched Tuna Chunks using HACCP systems. The hazards likely to occur and their levels of severity and chances of occurrences were identified. Critical control points, critical limits, control and preventive measures, corrective actions for non-conformances and verification procedures were evaluated and documented. ISO 22000 Analysis Worksheet was also employed for determination of some prerequisite programmes (PrPs) and compared with the HACCP decision tree table for determination of Critical Control Points (CCPs). The PrPs were the main difference between the two systems. The major hazards identified were the probable contamination with spoilage and pathogenic microorganisms - *Listeria monocytogenes*, *Clostridium botulinum*, *Salmonella* and *Staphylococcus aureus*; foreign materials - metal residues and sand; chemical contaminants - heavy metals, histamine and cleaning detergent residues, before, during and after processing. Using the HACCP decision tree, eight CCPs were identified, namely: fish receipt (CCP 1), frozen storage (CCP 2), racking and staging (CCP 3), metal detection (CCP 4), vacuum sealing (CCP 5), thickness rolling (CCP 6), retorting (CCP 7) and bulk incubation/seal testing (CCP 8). The incorporation of PrPs in the ISO 22000 made the system more flexible by reducing the number of CCPs (8 in the HACCP system) to 4 without compromising safety of the product.

Introduction

The fish processing industry observes strict safety and hygiene standards to meet regulatory requirements and ensure final product quality and safety. In addition, certain quality measures are put in place to prevent and control the occurrence of these hazards and the measures include Hazard Analysis Critical Control Points (HACCP), Good Manufacturing Practices (GMP's) and Good Hygienic Practices (GHP's).

HACCP is defined as "a system that identifies, evaluates, and controls hazards which are significant for food safety" (UNCTAD/WTO, 2002). It identifies all possible hazards that could occur in all the processes in the food manufacturing chain and finds preventive measures to ensure that the processes are controlled. The basis of HACCP was first developed in the 1960's by the Pillsbury Company in collaboration with the National Aeronautics and Space Administration (NASA) in an effort to develop a safe food product that could be used under zero gravity conditions by astronauts (Pearson and Dutson, 1995). The main challenge was to guarantee the safety of the food products. Although conventional quality control was being practiced at that time, it was expensive, destructive and generally focused on finding solutions after problems had occurred. It therefore became necessary to identify an approach that was preventive, hence the establishment of the HACCP system.

Although the application of HACCP begun in 1959, it was formally introduced to the public in 1971 and was adopted by food industries in the 1980's (Luning *et al*., 2002). Since then, it has been applied in several food industries to ensure the safety and quality of industrially processed foods.

In 2005, ISO developed a new food safety standard, the ISO 22000 – 'Requirements for Food Chain Organizations' (Blanc, 2006). The new standard, ISO 22000; incorporates management systems and food safety practices (HACCP and Pre-requisite programs) in the development of protocols for guaranteeing food product safety (Arvanitoyannis and Varzakas, 2009). ISO 22000 provides additional control in hazard prevention due to its focus on Prerequisite Programmes and integration of all parties directly and indirectly involved in the food chain (Blanc, 2006).

The Company under study is a tuna processing and packing establishment licensed by the European Commission (EC) through the Ghana Standards

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Authority (GSA) for the export of canned and pouched tuna products to member states. The company exports mainly to the European Union and is a member of industries in the Free Zone enclave in Ghana. The company produces sterilized tuna fish in cans and pouches. The production line includes tuna flakes, chunks and solid pack, each in either brine or vegetable oil. The company began production of canned tuna in 2002 and pouched tuna in 2007.

As part of the company's objective to produce and supply high quality and safe products, it adopted the HACCP system for all its product lines. Although HACCP provides an effective system for assuring food safety, it is often accompanied by many CCPs some of which require intense monitoring but still deliver much less than HACCP promises. Prerequisite programmes incorporated in ISO 22000 have been shown to reduce the number of CCPs, making the safety management system more flexible without compromising the product quality and safety.

The objective of this study was to apply the principles of HACCP and ISO 22000 as a means of providing preventive, advantageous strategies for minimizing food safety hazards while ensuring utmost product quality during the production of Vacuum-Packed Pouched Tuna Chunks in a food processing factory.

The HACCP system

The HACCP system was developed in 1959 for the North American Space Agency (NASA) space program as a preventive system of food control. Most quality assurance programmes, which existed at the time, were based on what the quality assurance manager believed was a good program (Pearson and Dutson, 1995). There was no uniformity or standardization and therefore companies could not provide the assurance required that the products were safe enough to be consumed. The old systems also resulted in the destruction of large amounts of product for testing since such a high amount was necessary to arrive at a statistically reasonable level of confidence in the product (Pearson and Dutson, 1995). The HACCP system was therefore created to achieve such high confidence in safety with significantly less testing.

As a preventive system, HACCP focuses on control over the raw materials, the process, the environment, personnel, storage, and distribution beginning as early in the system as possible (FDA, 1994). It aims to identify possible problems before they occur and establish control measures at stages in production that are critical to product safety. This kind of control, along with good record-keeping provides assurance of the product safety and therefore minimizes the amount of testing required (Silliker, 1995).

HACCP was first presented to the general public in 1971 at the United States' National Conference of Food Protection (Department of Health, Education and Welfare (DHEW, 1972). In 1973 it was applied to low acid canned food (FDA, 1973) and in 1987 it was developed for application in the fish and seafood processing industry (Pearson and Dutson, 1995). The HACCP system is defined as a result of implementation of an HACCP plan which is a written document that is based on the principles of HACCP and that delineates procedures to be followed (Luning *et al.*, 2002).

Developing a HACCP plan

Several articles have been published, which describe the HACCP principles and procedures for development and implementation of an HACCP plan (ICMSF, 1989; MFSCNFPA, 1993a, b; European Commission, 1996; Codex Alimentarius Commission, 1997; Leaper, 1997; NACMCF, 1992, 1998). There is a 12-stage procedure for the development and introduction of an HACCP plan, which includes five preliminary steps of HACCP and seven HACCP principles.

The five preliminary steps of HACCP as outlined by the National Advisory Committee on Microbiological Criteria for Foods (NACMCF) to help in developing an HACCP plan are:
Step 1: Assembling an HACCP Team, Step 2: Description of the product and its distribution, Step 3: Identification of intended use and consumers, Step 4: Development of process flow diagram (Leaper, 1997), and (Luning et al., 2002) and Step 5: On-site verification of the flow diagram.

Luning *et al.* (2002) stated that the seven HACCP principles which make up the sixth to twelfth steps of the 12-stage procedure for development and introduction of the HACCP plan are:
Principle 1: Hazard analysis, Principle 2: Critical Control Points (CCPs) identification (Pearson and Dutson, 1995), Principle 3: Establishment of critical limit(s) (FAO, 1997) and (Luning et al., 2002), Principle 4: Establishment of monitoring systems (FAO, 1997), Principle 5: Establishment of corrective actions, Principle 6: Establishment of procedures for verification and Principle 7: Establishment of documentation and record keeping.

Shortfalls of HACCP

HACCP plans unlike GMP's do not cover all areas of sanitary control in a food operation. Whereas

all GMP requirements are equal from a regulatory perspective, and span all areas of the food processing operation, HACCP narrowly focuses on specific areas where hazards might be introduced. For example, dust is filth under GMPs, and its presence on equipment is a violation. However, under HACCP, control of dust is a sanitary step but is not critical, because its presence is an unlikely safety hazard. Secondly, HACCP is a dedicated safety programme (i.e. solely focuses on safety issues), which cannot include quality points without a dilution of critical areas (Arvanitoyannis and Varzakas, 2008). It is therefore evident that, HACCP cannot exist as a stand-alone programme. Thus to achieve safety and quality, HACCP should be supported by a strong foundation of prerequisite programmes (Sperber, 1998). Prerequisite programmes are written, implemented procedures that address operational conditions and provide the documentation to help an operation run more smoothly to maintain a comprehensive food-safety assurance programme (Arvanitoyannis and Varzakas, 2008).

ISO 22000 approach

As food safety hazards may be introduced at any stage of the food chain, adequate control throughout the supply chain is essential. Based on this, in 2005, ISO developed a new food safety standard, the ISO 22000 – 'Requirements for Food Chain Organizations'. ISO 22000 is an international standard that defines the requirements of a food safety management system covering all organizations in the food chain from "farm to fork" (BSI, 2010), as food safety is a joint responsibility that is principally assured through the combined efforts of all the parties participating in the food chain (Faergemand and Jersperson, 2004). The standard combines generally recognized key elements to ensure food safety along the food chain, including: Interactive communication, System management, Control of food safety hazards through pre-requisite programmes and HACCP plans, Continual improvement and updating of the food safety management system (BSI, 2010). Basically, it is a combination of the management systems of ISO 9001 and food safety practices (HACCP and Pre-requisite programmes).

ISO 22000 dynamically combines the HACCP principles and application steps with prerequisite programmes, using the hazard analysis to determine the strategy to be used to ensure hazard control by combining the prerequisite programmes and the HACCP plan (Faergemand and Jersperson, 2004). The standard further clarifies the concept of pre-requisite programmes. These are divided into two subcategories: infrastructure and maintenance programmes and operational pre-requisite programmes. Infrastructure and maintenance programmes are used to address basic requirements of food hygiene and accepted good practice of a more permanent nature, whereas operational pre-requisite programmes are used to control or reduce the impact of identified food safety hazards in the product or the processing environment (Faergemand and Jersperson, 2004). Arvanitoyannis and Varzakas (2008) noted the main differences of ISO 22000 compared with HACCP and detailed the main advantages of ISO 22000 over HACCP elsewhere Arvanitoyannis and Varzakas (2008) and BSI (2010).

Tuna

Tuna fish belongs to the family Scombridae (Collette and Nauen, 1983). The family Scombridae is composed of 15 genera comprising 49 species of epipelagic marine fishes, which includes the Mackerels, Spanish mackerels, Bonitos and Tunas (Collette and Nauen, 1983). Tunas are extremely valuable commercially especially yellow fin (*Thunnus albacores*), skipjack (*Katsuwonus pelamis*), big-eyed (*Thunnus obesus*), frigate (*Auxis thazard*), eastern little tuna (*Euthynnus affinis*), and bullet tuna (*Auxi srochei*) (Industry Profile, 2001). Several industrial methods of processing tuna have been developed. These include canning, cold smoking, curing, and more recently, thermal processing in retort pouches.

Flexible retort pouches

The retort pouch is a flexible laminate that can be thermally processed in a way similar to that in which traditional cans are processed to produce shelf stable food products. Simpson (2008) noted that the development of the pouch began in the United States in early 1950's, by the U.S. Army Natick Development Center for military use. Reynolds Metal Company and Continental Can Company were the first civilian companies to be granted approval by the FDA for the production of retort pouches in 1977 (Simpson, 2008). During the 1980's, low-acid foods thermally sterilized in retort pouches were successfully marketed in Japan and Europe (Simpson, 2008).

Advantages of retort pouches

Retort pouches offer many more advantages for food manufacturers, consumers, and retailers than conventional metallic cans. Farber and Todd (2000) and Simpson (2008) have noted that the several advantages of retort pouches to include among others;

(i) Their flat geometry which provides a small

cross-sectional dimension that enables rapid heat transfer during thermal processing which results in energy savings with improvement of organoleptic attributes and nutritional quality, (ii) The lightweight and reduced storage space of empty pouches before processing resulting in lower transportation and storage costs for manufactures, (iii) The relatively low thickness and weight facilitate transportation and storage by consumers packaging of more products in less space, (iv) Retort pouches are more convenient to use (e.g., safe to open, minimum requirement for opening tools, etc) and (v) Saves shelf space during retail display.

Hazards associated with tuna processing

Several hazards have been identified with the production of vacuum-packed tuna; from the handling of the raw material (tuna), processing, through to storage and distribution. Some of these hazards lead to the spoilage of the fish whereas others result in pathogen proliferation in the fish, predisposing prospective consumers to severe illnesses and even death. These hazards are classified into microbiological, chemical and physical hazards.

Microbiological hazards

Tuna is a low acid food made up of 70% water, 23% protein, 1% lipid, less than 0.5% carbohydrate and 1.2 to 2.5% ash (Lund *et al.*, 2000). The relatively high pH and compositional attributes (high moisture and protein content) of tuna make it a suitable medium for microbial growth. Tuna tissues also contain high levels of free non-protein nitrogen (NPN) compounds, which are readily available to support post-mortem bacterial growth (Lund *et al*., 2000). The growth of these microbes could either lead to spoilage of the fish product or cause disease (infections or intoxication).

Several types of microorganisms have been found to be associated with fish during post-harvest handling, processing, storage and distribution of the fish. These include *Clostridium botulinum*, *Listeria monocytogenes*, *Clostridium perfrigens*, *Staphylococcus aureus*, *Salmonella* spp., *Shigella* spp., *Campylobacter* spp., *Aspergillus* spp. and *Penicillium* spp. (Hussain *et al.*, 1989; Garrett *et al*., 1997). Whether the contamination of microorganism will become a hazard or not depends on several factors during the production or processing of the raw materials. These factors are related to the hygienic environments during production, presence of inhibition or destruction step during processing and the conditions in the product/material regarding possible microbiological growth (Sonneveld, 2004).

Physical hazards

Physical hazards associated with fish include intrinsic physical hazards which are in the food by nature e.g. bones in fish, technical faults during harvesting, transportation and processing which might cause contamination with physical material (foreign bodies) such as metal, glass or plastic in raw materials or finished products.

Chemical hazards

Chemical hazards associated with processing tuna can be divided into three categories including intrinsic (chemicals which are already in fish production during post-harvest handling and storage) e.g. histamine and heavy metals such as mercury, and technical faults during processing which might contaminate the food with chemicals. These include detergent residues, packing materials containing poisonous material in contact with the fish, cleaning agents, metals dissolving in the product and maintenance materials such as diesel from forklifts and fishing vessels, lubricants from machine parts, etc. (Sonneveld, 2004).

Histamine

Histamine is a chemical formed in certain fish, especially scombroid fish, when it starts to decompose. Histidine, a naturally occurring amino acid, is converted into histamine by an enzyme produced by certain bacteria (CFIA, 2002; FDA, 2009). Histamine, in small doses, is necessary for the proper functioning of the human immune system. However, histamine may trigger severe allergic reactions (called scombroid poisoning) when consumed in high doses (CFIS, 2002; FDA, 2009).

The presence of high levels of histamine always indicates that decomposition has occurred, even if the decomposition is not obvious (CFIA, 2002). Toxic amounts of histamine can form before a fish smells or tastes bad. Histamine, once formed in fish cannot be destroyed or eliminated by heat treatment or freezing (Surak and Wilson, 2007; FDA, 2009). Formation of the toxin can however be controlled through proper chilling from harvest to process, and utilizing a detailed knowledge of the temperature history (Surak and Wilson, 2007).

Heavy metals

Heavy metals are metals which have a high atomic mass including mercury, cadmium, arsenic, and lead. Heavy metals are usually toxic in low amounts and are therefore a potential health hazard (IUFoST, 2008). Heavy metals mostly arise indirectly in fish from the environment (water) in which it lives. As such, once

they become incorporated into the fish they cannot be removed. Control of raw materials is, therefore, the only mechanism for ensuring that levels do not become unsafe (IUFoST, 2008).

Critical operations in processing of pouched tuna

Freezing of the fish

Once harvested, the change in natural environment, death, handling and exposure to atmospheric micro flora and physical conditions trigger the onset of spoilage and deterioration. Generally, the rates at which both autolytic and microbial spoilage take place are dependent upon the temperature at which the fish is stored. Deteriorative processes are retarded at reduced temperatures and, when the temperature is low enough, spoilage can almost be stopped (Hall, 1997).

The purpose of freezing fish is to lower the temperature even further thus slowing down spoilage such that when the product is thawed after cold storage it is virtually indistinguishable from fresh fish (Hall, 1997). Because handling conditions immediately after catching are responsible for the rapid loss of the "as-fresh" quality, the quality of thermally processed fish suffers whenever the raw material is temperature abused and/or physically damaged between catching and thermal processing.

Precooking

Precooking involves subjecting the raw material (tuna) to a relatively severe heat treatment (usually steam) at a specified temperature, pressure and time (Da-Wen, 2006). The precooking time depends on the size and species of the tuna, quality of the raw material, and the temperature along the backbone (Da-Wen, 2006). Precooking serves a number of functions: (i) To partially dehydrate the flesh and prevent release of those fluids during retorting which would otherwise collect in the container (FAO,1988); (ii) To remove excess natural oils, some of which have a strong flavour (Dagoon, 2005); (iii) To coagulate fish protein and loosen meat from the bones (FAO, 1988); (iv) To develop desirable textural and flavour properties in the final product (Dagoon, 2005; FAO, 1988).

Pre-cooking conditions affect yield and sensory quality it is important that they are regulated. Excessive treatment tends to reduce yields, whereas inadequate pre-cooking means that the purpose of the treatment is not achieved (FAO, 1988).

Filling of pouches

Filling of pouches can be critical to product safety, and hence it is imperative that it be carried out under strict control. Prior to filling it is important to ensure that the pouch is free from contamination and defects, as these would affect the integrity of the final product. During filling it is important to maintain a constant fill weight and/or temperature. This is because in processes where target F_0 values are recognized as close to the minimum for safety from botulism (e.g. F_0 = 2.8 to 3.0 min), even small variations in fill temperature or fill weight can have significant effects on the adequacy of the thermal process (FAO, 1988). Also, filling should not contaminate the seal areas of the pouch as this will result in imperfect sealing and impair the sterilization process (Sen, 2005).

Vacuum Sealing/thickness control of Pouches

The effective sealing of the filled pouch is an extremely important operation: the post process contamination of a heat-processed product is dependent upon a secure (hermetic) closing seal (CCFRA, 2006). Prior to sealing, it is an absolute necessity to deaerate the filled pouch (a process called vacuum packing). If air is left in the sealed pouch, it may result in the following problems: (i) During thermal processing, the air would inflate and burst the pouch (Sen, 2005) and (ii) It would impair the heat transfer, cause under sterilization and later be reflected by swelling of the pouch. Vacuum sealing assists uniform heat transfer during thermal processing (Sen, 2005). According to Sen (2005), the residual air in the pouch should not exceed 2% of the volume of the pouch content. Both air removal and sealing is done in one operation and is normally effected in an automatic line. It is also important that the pouches have a uniform thickness to ensure uniform sterilization of all the products as excessive pouch thickness could cause under sterilization.

Thermal processing (retorting)

Thermal processing involves, heating the packed product such that every location in the container would receive a pre-designated minimum thermal treatment. The key objective of this heat treatment is to ensure commercial sterility of the product, such that all pathogenic and spoilage microbes capable of growing under normal storage and handling conditions are destroyed (Da-Wen, 2006).

Among the spore-forming organisms, *C. botulinum* types A and B are the most heat resistant, constituting a potential health hazard (Da-Wen, 2006). For low-acid products with pH values greater than 4.5, such as packaged fish, the anaerobic conditions are ideal for growth and toxin production by *C. botulinum* (Da-Wen, 2006). Therefore, its destruction

is the critical parameter used in heat processing. The destruction of *C. botulinum* is normally achieved through application of a heat process that has a F_0 value equivalent in lethal effect to not less than 3 minutes at 121.1°C, resulting in product that is commercially sterile (CCFRA, 2006).

Retort pouches are processed in a specially adapted retort called over-pressure retorts (Hall, 1997; Sen, 2005; CCFRA, 2006). Pressure developed inside the pouch during thermal processing is very high. Although sealed pouches can withstand high external pressure, a small positive internal pressure even to the order of 0.1 kg/cm^2 resulting from the difference between internal and external pressures may result in bursting of the seal. It is for this reason that, while heat processing, it is necessary to introduce an additional compensating pressure into the retort in order to prevent bursting of the pouch or weakening the seal (Gopakumar, 1993).

Methodology

Application of HACCP in the processing of tuna

The 12-stage procedure for the implementation of an HACCP plan described earlier was adopted to the processing of tuna to produce vacuum pouched tuna chunks. A preliminary visit to the factory was carried out over a three week period to gain familiarity with the various operations involved in processing, as well as the processing plant layout. During the visit, staff and personnel were observed and interviewed concerning the existing GHP's and GMP's. The already established factory HACCP team was involved in the application of HACCP to the processing of tuna.

Description of product and its distribution

As part of the HACCP plan a full description of the product, which included all relevant safety information, was drawn up and this included the following aspects:

i. Composition and physical features of the final product - tuna are packed in water or vegetable oil and are either seasoned with salt, vegetable broth or xanthan gum depending on the specification by the customer; ii. Method of packaging - a four-layer laminate retort pouch is used a packaging material; iii. Storage conditions - the product is stored under ambient temperature (room temperature) of between 25 to 28°C; iv. Method of distribution - Labeled secondary packaged products are loaded into container trucks, transported to the harbour and are then shipped to the country of destination; v. Shelf life - the target shelf life of the products both in brine and vegetable oil is 2 years; vi. Instructions for use and storage by consumers - after opening the pouched product, any unused contents should be placed and covered in a food container, then stored in a refrigerator and used within 2 days; vii. Intended use and consumers - The intended use is ready-to-eat product, without further cooking, in a variety of fillings, salads and sandwiches or with minimal preparations into other dishes by the general population who are not allergic to tuna or any of the stated ingredients.

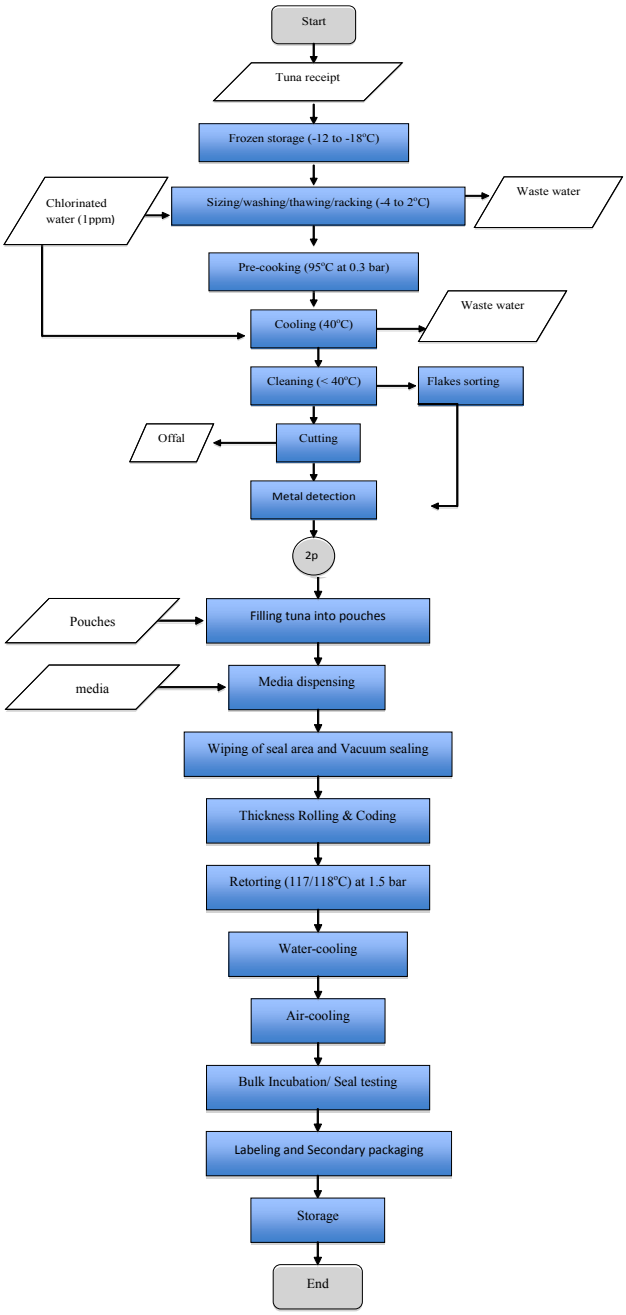

Figure 1. Flow chart for processing of vacuum-packed pouched tuna chunks

Process description

The process flow diagram (Figure 1), for the processing of vacuum-packed pouched tuna was

verified as required by HACCP implementation plan. The tuna received is inspected for good quality, unloaded, weighed and put in the cold store. The tuna is then sized, thawed and racked for pre-cooking. After pre-cooking the tuna is cooled and cleaned to remove blood meat, bones, scales and offal. Cleaned loins are then cut, passed through a metal detector, weighed and filled into pouches. Media (brine or oil) at 50°C is added in appropriate amounts and vacuum-sealed according to seal specification. Sealed pouches are passed through thickness roller and placed on retort racks for retorting. Retorted pouches are cooled and incubated for 14 days after which labeling and secondary packing is done and the product is dispatched for shipment.

Pre-processing operations

All preparatory operations prior to sterilization heat treatment used in food production are pre-processing operations (Hall, 1997) and in the case of vacuum pouched tuna chunks they include fish receipt and cold storage, thawing, racking, pre-cooking, cleaning, cutting, sorting, metal detection, filling, sealing and coding.

Fish receipt and cold storage

Tuna is purchased from fishing vessels officially approved by the Ghana Standards Authority in Tema, Ghana. Tuna purchased for processing include skipjack, yellow fin and big eye tuna which weigh between 1.36 kg to 10 kg. The tuna, before purchased, is inspected by quality assurance personnel for good quality. It is then unloaded into scows (large containers), weighed and transported to the company's cold store (-12 to -18°C). The factory is about 8 km away from the fishing harbour and has a good access road and it takes 15 min to transport frozen tuna from the vessel unloading site to the factory. Upon arrival at the factory, the following quality control measures used in fish collection are undertaken:

a. Backbone temperatures of randomly sampled fishes are checked to ensure that it meets the company's specification of -12°C to -18°C. Conformance to this temperature range prevents the onset of fish deterioration and development of histamine.

b. The following attributes are inspected for fresh fish received for processing: (i) Bright, shiny and firm skin with transparent mucus, (ii) Bright and bulging eyes with crystal clear cornea, (iii) Bright red or pink gills, (iv) No skin discoloration and (v) No foul smell.

c. Plastic scows are preferably used by the company for fish collection to minimize introduction of metallic chips (which usually occurs when metallic scows are used) into the fish.

Sizing/Washing/Thawing/Racking

Fish selected for processing are thawed to reduce precooking time. Thawing involves bringing down the fish from cold storage, reweighing and transferring to the thaw area. The fish backbone temperature is then checked and recorded and the fish are arranged according to sizes (sizing) on pre-cooker baskets and racks, a process called racking. The arrangement of the fish by sizes in the racking process is done to ensure effective heat transfer during pre-cooking such that smaller fish do not get over cooked.

Actual thawing involves placing racked fish under running water within a temperature range of 23°C to 29°C. The optimum temperature is 25°C. Thawing is done until fish attains a temperature range of -4 to 2°C. Above this temperature range, histamine levels in the fish begin to increase. By thawing, fish is washed at the same time, removing any traces of sand and other foreign materials which may have been introduced during harvesting and handling.

Pre-cooking

Depending on species, size and backbone temperature, thawed fish are subjected to heat treatment within a temperature range of 93°C to 95°C, at 0.3 bar pressure, until the desired backbone temperature range of 55°C to 57°C is reached. Precooking involves loading pre-cooker with racks of fish, setting the chamber temperature to 95°C and heating it for the specified time. Once the precooking has been completed, the front racks are removed and random backbone temperatures are taken (i.e. 3-5 pieces per rack). If the average reading is within or above the target temperature range the cooker is unloaded. If the average is less than the target, the racks are pushed back into the pre-cooker and additional cook time is given.

Precooking reduces initial microbial load, deactivates certain enzymes and facilitates subsequent processes such as cleaning. Following precooking, fish are sprayed continuously with potable water (cooling) until fish backbone temperature reaches a desired temperature range of 31°C to 40°C. After this stage, the cooled fish are distributed to fish cleaners for cleaning.

Cleaning

Cleaning involves de-heading, de-boning, skin and scale removal, degutting and removal of belly portion and blood meat. These parts of the fish are removed and disposed of because they are generally considered unusable for processing. Skin and blood meat removal ensures uniformity in colour of the product for presentation purposes. Cleaning also

involves polishing of the loins. This involves breaking of fish into two halves along the dorso-ventral axis. Each half is further broken into two longitudinal halves called the loins. The loins are polished by rubbing them against the palm. This process generates flakes of fish flesh. However rubbing is done gently to prevent generating excess flakes and breaking the loins. The belly portions are washed, mixed with the generated flakes and undergo further processing to be used in subsequent preparations.

Cutting/ sorting and metal detection

Loins are arranged on trays, inspected to ensure they are devoid of bones and cut into pieces suitable for packaging. They are then passed through a metal detector to check for metallic contamination and sent for pouch packaging. Flakes are also sent to the sorting room, where blood meat and bones are removed. This is done under low temperatures (17°C - 20°C) and quickly to prevent histamine build-up. The flakes are thereafter passed through the metal detector and sent for pouch packaging.

Pouch filling/sealing/coding/thickness rolling

Prior to filling, pouches are thoroughly inspected to ensure that they do not have any defects such as punctures and scratches. Pouches inspected and confirmed to be devoid of defects are filled with fish (solids and flakes) according to client specifications. Percentage composition of media (brine or oil) of acceptable temperature is added from a measuring jug to each filled pouch and vacuum-sealed according to seal specification. Vacuum sealing removes air from the package which when left will reduce the efficiency of heat penetration. The sealed pouches then pass through a rolling machine, which controls the thickness (excessive pouch thickness could cause under sterilization) and ensure uniformity in pouch thickness, after which they are coded and placed on retort racks for thermal processing.

Thermal processing (retorting)

Thermal processing involves, heating the packed product such that every location in the container would receive a pre-designated minimum thermal treatment. Retort pouches are processed in specially adapted retorts called over pressure retorts at a temperature of 117°C - 118°C and a pressure of 1.5 bar. The duration of the process depends on a variety of factors such as, type and size of the product and container. In order to determine the adequacy of the heat process, F_0 charts are plotted frequently. F_0 value is a measure of the effective sterilization of a heat process. For low acid canned foods produced, it is the policy to sterilize to an absolute minimum F_0 value of not less than 3. However, the company targets an F_0 value of 6 minutes for precautionary reasons.

Post processing operations

All operations after the sterilization heat treatments are post processing operations and these include cooling, incubation, labeling and storage.

Cooling/ bulk incubation

After thermal processing, the pouched products are cooled with water to a temperature of 45 - 50°C. The pouches are dried with clean rugs, air cooled to room temperature and then subsequently stored in a warehouse for 14 days (a process referred to as bulk incubation) to quarantine the product and ensure that there are no defects in the product.

Labeling/secondary packaging/storage

Pouches with no defects are labeled for identification purposes, packed into boxes (secondary package) and stored in a warehouse at ambient conditions (25°C to 28°C) until ready to be shipped.

On-site verification of flow diagram

The operation process was inspected to verify that each step in the flow diagram was an accurate representation of the actual situation.

Hazard analysis

Hazard analysis was conducted by undertaking three-stage activities comprising; composing a list of all potential hazards (physical, chemical and microbiological) that are reasonably likely to occur during processing, evaluating potential hazards based on severity and likely occurrence and lastly designating preventive or control measures to be applied for each hazard.

ii. Determining pre-requisite programmes using ISO 22000 approach

Determination of pre-requisites programmes (PrPs) was done by employing ISO 22000 Analysis Worksheet (Arvanitoyannis and Varzakas, 2008; 2009).

iii. Determining the CCPs in the production line using both HACCP and ISO 22000 approach

CCPs according to HACCP were determined using HACCP decision tree. CCPs according to ISO 22000 were determined by comparative analysis between CCPs according to HACCP and determined pre-requisite programmes.

iv. Establishing a monitoring system for pre-determined Critical Control limits. This was done by designing documents and schedules for the

measurement and/or observation of CCP relative to their critical limits and assigning people with relevant knowledge to evaluate and sign the monitoring data.
v. Applying a systematic problem-solving approach for corrective action

This was done by determining and correcting the cause of non-compliance (non-conformance) and recording the corrective action taken.

Results and Discussion

The scope of this project included undertaking a Hazard analysis, determining Critical Control Points (CCPs) and Prerequisite Programmes (PrPs), and the development of a monitoring system for the Critical Control Points. The comparison between application of HACCP and ISO 22000 was also made. The results of these activities are presented in Tables 1 to 5.

Table 1 shows the hazard analysis worksheet identifying the different hazards at each processing stage, their causes, their preventive and control measures, when and by whom follow up will be given to the control and preventive measures. The last column Document/system makes reference to the document in which the control and preventive measures are stipulated. Step 0 makes reference to the prerequisite, which is also subject to the Hazard Analysis and Risk Assessment.

Table 2 presents an ISO 22000 analysis worksheet for the determination of prerequisite programmes for pouched tuna processing and Table 3 shows the determination of Critical Control Points (CCPs) according to the decision tree diagram. Table 4 summarizes the findings of the previous two tables displaying the CCPs according to HACCP and ISO 22000 taking into account the effect of implementation of prerequisite programmes in the industrial processing of pouched tuna. Finally, Table 5 shows the monitoring system developed for the CCPs, including their preventive measures, critical limits, corrective actions, assignment of responsibilities and verification procedures.

Hazard analysis

In Table 1, the different processing steps are each associated with different risk assessment values, which range widely from the least 1 to the highest 16. The risk assessment values are obtained by multiplying the occurrence and severity values and it serves to choose, among the hazards listed for a food, those that are likely enough or severe enough to warrant preventive action (Varzakas and Arvanitoyannis, 2009). For instance, a hazard such as contamination of product with cleaning and sanitizing agents like chlorine and soap under the cleaning processing step has an associated assessment of 1 because likelihood of occurrence is low (because proper cleaning protocols are followed) and severity is low (because it does not pose serious health risks), whiles microbial contamination associated with fish receipt has a risk assessment of 16 because fish has a high occurrence of contamination with spoilage and pathogenic microorganisms which are of severe health and quality concern.

The major hazards identified in the production of the pouched tuna were of microbiological, chemical and physical origin as indicated in Table 1. The most predominant chemical hazard that was identified was histamine contamination (caused by the action of microorganisms coupled with favourable temperature which was present in seven processing steps, namely; fish receipt, frozen storage, sizing and thawing, racking and staging, cooling, cleaning and flakes sorting.

Physical hazards were identified in only four processing steps - fish receipt, cutting, metal detection and media preparation. The most dominant physical hazard was the presence of metal chips/residues, which have severe impact on the safety and quality of the product. Out of the four processing steps that had physical hazards, the hazard associated with fish receipt had the highest risk assessment value of 16 due to its high severity and occurrence. Compared to the physical and chemical hazards, the microbiological hazards were present/identified in almost every processing step and in each instance, were associated with a high-risk assessment value. This is because the raw material (fish) is highly susceptible to microbial contamination because it serves as an excellent substrate for microbial growth. The microorganisms, through their metabolic activities or presence cause food infections, spoilage or intoxications which are of severe health concern.

Critical control point determination

The CCP Decision Tree is a tool used to determine the right CCPs for each processing stage in HACCP. Table 3 shows the HACCP decision tree as applied to the processing of vacuum-packed pouched tuna and the resulting CCPs.The requirements for ISO 22000 assume the determination of the prerequisite programmes (Table 2). The questions frequently asked for each processing step involve questions regarding the adequacy of the technical infrastructure and preventative maintenance, the feasibility for their evaluation, their contribution in the control of recognizable food safety hazards, whether the effectiveness of the remaining control measures

Table 1. Hazard analysis worksheet

PRODUCT: Vacuum Packed Pouched Tuna Chunks

PROCESS: Fish receipt, Frozen storage, sizing/thawing Racking/staging, Precooking, Cooling, Cleaning, Flakes sorting, Cutting, Metal detection, filling, Vacuum Sealing, Thickness control, Retorting, Cooling, Bulk incubation/seal testing, Labeling/Secondary packaging, storage

NR	Process step	Hazard	CAT	Cause	O	S	RA	Explanation for occurrence and severity	Control & preventive measures	When	By whom	Document/ system
0	Water	Contamination with spoilage and pathogenic microorganisms such as *Staphylococcus aureus* and *E. coli*	M	Damaged pipelines in the factory and contamination from source.	1	4	4	Occurrence is very unlikely because water is treated and chlorinated on site but is considered to be very severe to human health	1. Check the pipelines frequently for leakages or damages.	1. Once a week	Plumber	Preventive maintenance report
									2. Chlorinate the water	2. Every 2 hours	Quality Assurance Manager	Chlorination report
									3. Organoleptic checks	3. Every 2 hours		
1	Fish receipt	Contamination with *Listeria monocytogenes*, *Clostridium botulinum*, *Salmonella* or *Staphylococcus aureus* etc	M	Contamination from natural environment of fish, post-harvest handling, and transport prior to arrival	4	4	16	Fish has a high occurrence of contamination with spoilage and pathogenic microorganisms which are of severe health and quality concern	1. Ensure standard quality on arrival	For every batch received	Quality Assurance Manager	Standard specification checklist for raw fish sensory examination, Vessel and scows sanitation inspection report
									2. Establish specification			
									3. Establish control at supplier levels			
1	Fish receipt	Contamination with metal pieces, and other foreign materials	P	Metal pieces from rusted metal scows and fishing equipment such as hooks	4	4	16	Fish has a high occurrence of varied physical contaminants from source (ocean), handling and transport. Severity on human health and product quality is high.	1. Check each delivery and ensure standard quality on arrival	Every batch received	Quality Assurance Manager	Vessel, transport and scows sanitation and inspection report.
									2. Educate personnel on board vessels on best hygiene practices.			
									3. Inspect vessels			
									4. Implement GMP's and GHP's			
									5. Avoid use of metal scows			
		Contamination with diesel	C	Fish can be contaminated with diesel from forklifts during movement from one point to another	1	4	4	Likelihood of occurrence is low because most of the forklifts used are properly maintained and faulty forklifts are not used. Severity on human health and product quality is high	1. Use gas or battery powered forklifts, or regular maintenance of diesel forklifts.	Every day	Production Manager	Preventive maintenance report
									2. Check each delivery and ensure standard quality on arrival	Everyday	Quality Assurance Manager	Standard specification checklist for raw fish sensory examination
1	Fish receipt	Contamination with heavy metals	C	Heavy metals are present in the plankton consumed by the fish	1	4	4	Likelihood of occurrence is very low because areas with heavy metals are known and fishing is prohibited in those areas. Severity is very high because high levels of heavy metals in fish has adverse health consequences	1. Sampling for heavy metal analysis before fish is purchased.	Every batch received	Quality Assurance Manager	Heavy metal analysis report
									2. Buy tuna from vessels that fish from approved fishing grounds			
		Histamine buildup	C	Temperature fluctuations aboard vessel and delays during transfer	2	4	8	Likelihood of occurrence is relatively low because vessels are audited before fish is purchased and fish is transported over a short distance. High levels of histamine a severe impact on human health.	1.Sampling for histamine analysis before fish is purchased	Every batch received	Quality Assurance Manager	Histamine analysis report
									2. Buy tuna from vessels approved by the Ghana Standards board			
2	Frozen storage	Growth of microorganisms	M	Temperature fluctuations in cold store	1	4	4	Likelihood of occurrence is low because there's a good system of power supply and a good maintenance system. High microbial load has severe impact on product safety	1.Regular monitoring of cold store temperature	Every two hours	Quality Assurance Manager	Cold store temperature chart/log book
									2. Good cold store maintenance practices	Every week or on demand	Production Manager	Preventive maintenance file
		Ammonia contamination	C	Leakages of refrigerant	1	1	1	Likelihood of occurrence is low because of good maintenance systems. Severity is low because ammonia contamination does not pose serious health risks	Regular maintenance of cold store	Regular daily checks	Production Manager	Frozen tuna sensory examination report
		Histamine buildup	C	Temperature fluctuations in cold store	1	4	4	Likelihood of occurrence is low because there's a good system of power supply and a good maintenance system. High levels of histamine causes scombroid poisoning	Regular monitoring of cold store temperature	Every two hours	Quality Assurance Manager	Cold store temperature monitoring report
3	Sizing and Thawing	Chlorine contamination	C	Excessive chlorine in thawing water	1	1	1	Likelihood of occurrence is low because of regular checks of chlorine levels by QA. Severity is low because over-chlorination does not produce highly toxic products	Regular checks of chlorine level in water	Every 45 minutes	Quality Assurance Manager	Chlorine checks report
		Histamine buildup	C	Delays in sizing and over thawing	1	4	4	Likelihood of occurrence is low because fish is brought to the thawing area with average backbone temperatures of -9°C so temperatures are not likely to rise above +2°C. Severity is high because high levels of histamine cause	Regular backbone temperature checks and no delays during sizing of fish	Every 30 minutes	Quality Assurance Manager	Thawing /racking and staging report

Table 1 continued:

								scombroid poisoning				
4	Racking and staging	Histamine buildup	C	Delays prior to precooking	1	4	4	Likelihood of occurrence is low because process time schedules are complied with. Severity is high because high levels of histamine cause scombroid poisoning	Ensure that temperature does not exceed +2°C before precooking.	Every precooking batch	Quality Assurance Manager	thawing /racking and staging report
5	Precooking	Chlorine contamination	C	Excessive chlorine in precooker cooling water	1	1	1	Likelihood of occurrence is low because of regular checks of chlorine levels by QA. Severity is low because chlorine levels cannot reach toxic levels	Regular checks of chlorine level in water	Every 45 minutes	Quality Assurance Manager	Chlorine checks report
6	Cooling	Histamine buildup	C	Prolonged cooling	1	4	4	Likelihood of occurrence is low because process time schedules are complied with. Severity is high because high levels of histamine cause scombroid poisoning	Complying with process time schedules/ Ensuring appropriate GMPs	Every cooling batch	Quality Assurance Manager	Precooking report
		Chlorine contamination	C	Excessive chlorine in cooling water	1	1	1	Likelihood of occurrence is low because of regular checks of chlorine levels by QA. Severity is low because chlorine levels cannot reach toxic levels	Regular checks of chlorine level in water	Every 45 minutes	Quality Assurance Manager	Chlorine checks report
7	Cleaning	Cross contamination of pathogenic and spoilage microorganisms	M	Cross contamination can occur from personnel and equipment	1	4	4	Cross contamination can occur if appropriate GHPs and good sanitation practices are not adhered to. Severity is high because it can have adverse health effects.	1.Ensure appropriate GHPs 2. Good sanitation practices	Every cleaning batch	Production Manager	Sanitation report
		Contamination with cleaning and sanitizing agents like chlorine and soap	C	Contamination from personnel, equipment and surfaces	1	1	1	Likelihood of occurrence is low because proper cleaning protocols are followed. Severity is low because it does not pose serious health risks	1. Ensure good sanitation practices 2. Ensure appropriate GHPs	Every cleaning batch	Sanitation inspectors	Sanitation report
	Cleaning	Histamine buildup	C	Delays during cleaning of fish coupled with recontamination from personnel and equipment	1	4	4	Likelihood of occurrence is low because delays are unlikely. High histamine levels will cause scombroid poisoning.	1.Ensure proper GMP and GHP 2. Complying with process time schedules	Every cleaning batch	Production Manager	Cleaned loins inspection report
8	Flakes sorting	Histamine buildup	C	Delays during sorting and handling activities	2	4	8	Delays and handling will increase microbial activity, which will lead to histamine buildup. High histamine levels will cause scombroid poisoning.	Complying with process time schedules/ Ensuring appropriate GMPs	Every batch	Production Manager	Working instruction and checklist
9	Cutting	Contamination with metal residues	P	1.Chipping of cutting edge of (guillotine) machine 2. bolts and nuts from the guillotine machine	1	4	4	Metal chippings may arise from gradual degradation of the cutting edge. This is however unlikely because of constant maintenance. Severity is high because it has serious health risks 2. nuts and bolts could fall into the fish if not screwed in place properly. This is not likely to occur since the machine is thoroughly maintained.	1.Regular maintenance of the cutting machine 2. Good maintenance practices	1. Daily 2. Every maintenance session	Production Manager Production Manager	1. Preventive maintenance report 2. Preventive maintenance report
		Microbial contamination	M	Cross contamination from cutting edge to loins due to poor sanitation practices	1	4	4	Likelihood of occurrence is low because the cutting edge is cleaned and sanitized regularly. Severity is high because microbial contamination could pose serious health risks.	1.Sanitize the cutter 2. Ensure appropriate GHP	After every hour	Production Manager	Cleaning report for guillotine machine
10	Metal detection	Presence of metal pieces in the fish	P	Malfunctioning of metal detector	1	4	4	Metal pieces may escape detection due to malfunctioning of metal detector. This is however unlikely because metal detector is checked and calibrated hourly. Severity is high because it compromises quality and has the potential to cause physical injury to consumers	1.Proper and regular maintenance of metal detector 2. Calibration of metal detector	Daily Every hour	Production Manager Metal detector operators	Metal detection report
11	Empty pouch receipt	No known hazards	–	–	–	–	–	–	–	–	–	–
12	Filling tuna into pouches	Microbial contamination	M	Cross contamination from personnel and equipment used	1	4	4	Cross contamination can occur if appropriate GHPs and good sanitation practices are not adhered to. Severity is high because it can have adverse health effects.	1, Ensure proper GHPs	Constantly	Quality Assurance Manager	Working instruction, Checklist, GHP
13	Media preparation and dispensing	Microbial contamination	M	Cross contamination from equipment and personnel	1	4	4	Cross contamination can occur if appropriate GHPs and good sanitation practices are not adhered to. Severity is high because it can have adverse health effects	1. Ensure appropriate GHPs	Constantly	Quality Assurance Manager	Working instruction, Checklist, GHP
		Contamination of media with detergent/chlorine residues	C	Improperly rinsed equipment (e.g. media bowl)	1	2	2	Likelihood of occurrence is low because proper cleaning protocols are followed. Severity is low because it does not pose serious health risks	Good sanitation procedures	Constantly	Quality Assurance Manager	Daily sanitation inspection report
		Contamination with sand, stones, metal pieces	P	These contaminants may be present in the salt	1	4	4	Likelihood of occurrence is low because properly refined salt is used. Severity is relatively low	1.Use properly refined salt 2. Use media filters		Quality Assurance Manager	

Table 1 continued:

14	Vacuum sealing	Microbial growth	M	Improper sealing of pouch will lead to retention of air, which will also support microbial growth and activity	1	4	4	Likelihood of occurrence is very low because of strict adherence seal strength specification and residual air testing. Severity is very high because it can pose serious health risks	1.Proper maintenance of sealing machine 2. Visual Inspection of all sealed pouches 3. Seal strength checks to ensure machine is working properly 4. Residual air testing	1. Daily 2. All pouches sealed 3. Every hour 4. 3 times a day	1. Production Manager 2. Quality Assurance Manager 3. Quality Assurance Manager 4. Quality Assurance Manager	Preventive maintenance report 2.visual seal inspection report 3. seal strength checks report 4. Residual air checks report
13	Thickness rolling	Microbial growth	M	Faulty thickness roller will cause non uniformity in the pouch thickness which may lead to under sterilization of products	1	4	4	Likelihood of occurrence is very low as a result of strict adherence to pouch thickness specification. Severity is very high because it can pose serious health risks	1.Proper and regular maintenance of thickness roller 2.pouch thickness control	Daily Every 30 minutes	Production Manager Quality Assurance Manager	Daily pouch thickness control report
14	Retorting	Microbial survival and growth	M	Under sterilization due to 1. faulty retort (e.g. faulty circulating fan) 2.operator error	1	4	4	Likelihood of occurrence is low because temperature and pressure gauges are calibrated regularly and also regular checks are performed to ensure proper functioning of retorts	1.Proper and regular maintenance of retorts 2. Regular heat penetration tests 3. Personnel training 4. Commercial sterility checks 5. Calibration of equipment	1. Daily 2. Daily 3.Once a month 4. Every batch 5. Twice a day	1. Production Manager 2. Quality Assurance Manager 3. Training team	1.Preventive maintenance report 2. heat penetration test report
15	Cooling	No known hazards		–	–	–	–	–	–	–	–	–
16	Bulk Incubation/ Seal testing	Microbial recontamination	M	Mishandling may lead to puncturing of the pouch and loss of pouch seal strength which will pave way for microbial entry	1	4	4	Occurrence is not likely because pouches are handled well trained and experience staff. Severity is high because microbial contamination could pose serious health risks	1. Ensure appropriate GMPs 2.Ensure careful handling of pouch products 3. 100% inspection of finished products after 10 days incubation 4. post retorted pouches seal strength should not be below 50N	Every batch	Quality Assurance Manager	Post seal strength testing report, bulk incubation inspection report and laboratory incubation report
17	Labeling and Secondary packaging	No known hazards	–	–	–	–	–	–	–	–	–	–
18	Storage	No known hazards	–	–	–	–	–	–	–	–	–	–

NR = Number, CAT = Category, O = Occurrence, S = Severity, RA = Risk Assessment
1 = lowest rank and 4 = highest rank in the occurrence and severity columns
The Figure presented in the risk assessment column is the product of the occurrence and severity values.

Table 2. ISO 22000 analysis worksheet for the determination of prerequisite programmes for Vacuum Pouched Tuna processing

Processing step	Are the technical infrastructure and preventive maintenance program adequate?	Is it feasible to evaluate them?	Do they contribute in the control of recognizable food safety hazards?	Does the effectiveness of the remaining control measures depend on them?	Is it a prerequisite program?
Fish receipt	Yes	Yes	No	No	No
Frozen storage	Yes	Yes	No	No	No
Sizing and Thawing	Yes	Yes	No	Yes	Yes
Racking and staging	Yes	Yes	No	Yes	Yes
Precooking	Yes	Yes	No	Yes	Yes
Cooling	Yes	Yes	No	Yes	Yes
Cleaning	Yes	Yes	No	Yes	Yes
Flakes sorting	Yes	Yes	No	–	Yes
Cutting	Yes	Yes	No	Yes	Yes
Metal detection	Yes	Yes	No	No	No
Empty pouch receipt	–	–	–	–	-
Filling tuna into pouches	Yes	Yes	No	Yes	Yes
Media preparation and dispensing	Yes	Yes	No	No	Yes
Vacuum sealing	Yes	Yes	No	No	Yes
Thickness control	Yes	Yes	No	Yes	Yes
Retorting	Yes	Yes	No	No	No
Water/air cooling	Yes	Yes	No	No	Yes
Bulk Incubation/ Seal testing	Yes	Yes	No	–	Yes
Labeling and Secondary packaging	–	–	–	–	–
Storage	–	–	–	–	–

Table 3. Decision tree table

Processing step	Cause of hazard	Q1. Do preventive control measures exist?	Q2. Is the step specifically designed to eliminate or reduce the likely occurrence of hazard to an acceptable level?	Q3. Could contamination with identified hazards(s) occur in excess or could this increase to unacceptable levels?	Q4. Will a subsequent step eliminate identified hazards(s) or reduce likely occurrence to acceptable levels?	Is this step a critical control point?
Fish receipt	Microbiological hazard	Yes	Yes	_	_	CCP 1
	Chemical hazards	Yes	Yes	_	_	CCP 1
	Physical hazards	Yes	No	Yes	Yes	Not CCP
Frozen storage	Microbiological hazards	Yes	Yes	_	_	CCP 2
	Chemical hazards	Yes	Yes	_	_	CCP 2
Sizing and Thawing	Chemical hazards	Yes	No	No		Not CCP
Racking and staging	Chemical hazards	Yes	No	Yes	No	CCP 3
Precooking	Chemical hazards	Yes	No	No	_	Not CCP
Cooling	Chemical hazards	Yes	No	No	_	Not CCP
Cleaning	Microbial hazards	Yes	No	Yes	Yes	Not CCP
	Chemical hazards	Yes	No	No	_	Not CCP
Flakes sorting	Chemical hazard	Yes	No	No	_	Not CCP
Cutting	Metal residues and Microbial contamination	Yes	No	Yes	Yes	Not CCP
Metal detection	Physical hazards	Yes	Yes	_	_	CCP 4
Empty pouch receipt	No known hazard	_	_	_	_	_
Filling tuna into pouches	Microbiological hazards	Yes	No	Yes	Yes	Not CCP
Media preparation and dispensing	Microbiological hazards	Yes	No	No	Yes	Not CCP
	Chemical hazards	Yes	No	No	_	Not CCP
	Physical hazards	Yes	No	No	_	Not CCP
Vacuum sealing	Microbiological hazards	Yes	Yes	_	_	CCP 5
Thickness control	Microbiological hazards	Yes	Yes	_	_	CCP 6
Retorting	Microbiological hazard	Yes	Yes	_	_	CCP 7
Water/air cooling	No known hazards	_	_	_	_	_
Bulk Incubation/ Seal testing	Microbiological hazards	Yes	Yes	_	_	CCP 8
Labeling and Secondary packaging	No known hazards	_	_	_	_	_
Storage	No known hazard	_	_	_	_	-

Table 5. Monitoring system

CCP	Step	Why	Preventive measures	Set value Tolerances Critical limits	Frequency of checking	Title of Procedure and/or working Instruction	Corrective action	Registration	Responsibility	Verification
1	Fish receipt	Microbial spoilage resulting in histamine formation	-Purchase fish vessels officially approved by the Ghana Standards Board -Fish from each batch should be tested according to defined sampling plan for histamine content	Frozen tuna backbone temperature ≤ -9°C. Histamine content ≤ 20ppm	Every delivery batch	Working instructions, Reference form	Reject lot if backbone temperature exceeds 9°C and if histamine content exceeds 20ppm	Suppliers delivery report	Quality Assurance Manager	-Daily review of records by the QA manager. -Proficiency testing for histamine should be undertaken at least 4 times each year with the Ghana Standards board
2	Frozen storage	Microbial spoilage resulting in histamine formation	Correct operation and 100% recording	-12°C to -18°C	Every hour	Working instructions, Reference form	Stop freezing and check cause of non compliance	Non conformance report	Quality Assurance Manager	Review of records by QA manager
3	Metal detection	Metal pieces present in fish could cause harm to consumer	All fish must pass through the metal detector prior to filling into pouches	Metal detector set up using test pieces. Fe=2.0mm Non-Fe = 2.5 mm Stainless steel = 4.77 mm	Every batch of loins and flakes	Working instructions, Reference form	Isolate contaminated loins and flakes and then inform QA manager for re-check and reject contaminated portion	Non conformance report	Quality Assurance Manager	Daily metal detector monitoring report must be reviewed an countersigned by QA manager
4	Retorting	Under sterilization will lead to growth of spoilage and pathogenic microorganisms	-Monitoring of process temperature and time. -Check all instruments for apparent serviceability and calibration prior to startup	All thermal processes must be within -5°C to +1°C of scheduled temperature and not less than process time	Each sterilization batch	Working instructions, Reference form	Refer to process deviation and alternative procedure instructions. Document all actions on sheet. Notify Q. A/Prod. Manager and Maintenance Supervisors required	Non conformance report	Production Manager	Daily review of all records including process deviation records by QA manager

depends on them. These questions lead to the answer of a programme being prerequisite or not.

Using the HACCP decision tree, eight CCPs were obtained for the process and using the ISO 22000 worksheet, the number of CCPs was reduced to four. This is presented in Table 4. Certain CCPs according to HACCP were not CCPs according to ISO 22000 because they were found to be prerequisite programmes in the processing line. For example, Racking and staging was identified to be a prerequisite programme and hence not a CCP according ISO 22000 because the histamine hazard associated with this step is effectively controlled by strict adherence to process time schedules.

Conclusion

The major hazards identified in the production of the Vacuum-Packed Pouched Tuna Chunks were the probable contamination with spoilage and pathogenic microorganisms (such as *Listeria monocytogenes*, *Clostridium botulinum*, *Salmonella* and *Staphylococcus aureus*), foreign materials (such as metal residues and sand), and chemical contaminants (such as heavy metals, histamine and cleaning detergent residues) before, during and after processing. However, effective control, preventive maintenance systems and verification procedures could be implemented to ensure the safety and quality of the product from fish reception through to the final product.

Using the HACCP decision tree, eight CCPs were identified which were fish receipt (CCP 1), frozen storage (CCP 2), racking and staging (CCP 3), metal detection (CCP 4), vacuum sealing (CCP 5), thickness rolling (CCP 6), retorting (CCP 7) and bulk incubation/seal testing (CCP 8). Using the ISO 22000 approach, which incorporates Prerequisite programmes, four (4) CCPs were identified, making the system more flexible without compromising the safety of the product. The CCPs removed were racking and staging, thickness rolling, vacuum sealing and bulk incubation and the remaining CCPs according to ISO 22000 were fish receipt, frozen storage, metal detection and retorting, which were identified as most critical to the finality and safety of the Vacuum Packed Pouched Tuna.

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