Course Manual on

Shrimp Processing and Quality Assurance for Export

AU-Avanti Aquaculture Skill Development Centre

(AU-Avanti ASDC)

Established by Avanti Foundation

New Building, MLR Department, Andhra University
Visakhapatnam, Andhra Pradesh

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Credits

Course Designed By:

1. **Prof. P. Janakiram,** Head of the Department, MLR Department, Andhra University, Visakhapatnam
2. **Dr. A.K. Reddy,** Principal Scientist (Retd.) , ICAR-Central Institute of Fisheries Education (ICAR-CIFE), Mumbai
3. **Dr. B. Madhusudana Rao,** Principal Scientist, ICAR-Central Institute of Fisheries Technology (ICAR-CIFT), Visakhapatnam Research Centre
4. **Sri. Chidambar Nadiger,** COO, Avanti Frozen Foods Pvt. Limited
5. **Sri. B. Manmadha Rao,** Quality Assurance Manager, Sprint Exports, Visakhapatnam
6. **Sri. S. Mohanty,** General Manager, Avanti Feeds Limited
7. **Dr. R. Prasad Naik,** Assistant Director, MPEDA, Visakhapatnam
8. **Dr. P. Srinivasa Rao,** Senior Technical Manager, Avanti Feeds Limited
9. **Dr. K. Phani Prakash,** Administrator, AU-Avanti Aquaculture Skill Development Centre, Visakhapatnam

Content Contributors:

1. **Dr. B. Madhusudana Rao,** Principal Scientist, ICAR-CIFT, Visakhapatnam Research Centre
2. **Sri. Chidambar Nadiger,** COO, Avanti Frozen Foods Pvt. Limited
3. **Dr. Viji P.,** Senior Scientist, ICAR-CIFT, Visakhapatnam Research Centre
4. **Dr. Jesmi Debbarma,** ICAR-CIFT, Visakhapatnam Research Centre
5. **Dr. K. Ahamed Basha,** Scientist, ICAR-CIFT, Visakhapatnam Research Centre
6. **Sri. B. Manmadha Rao**, Quality Assurance Manager, Sprint Exports
7. **Dr. J. Bindu**, Principal Scientist & HoD (Fish Processing Division), ICAR-CIFT, Kochi
8. **Sri. Sudhansu Sekhar Das**, OIC, EIA, Visakhapatnam
9. **Dr. K. Phani Prakash**, Administrator, AU-Avanti Aquaculture Skill Development Centre, Visakhapatnam
10. **Dr. D. Sunil Kumar**, Research Scientist, AU-Avanti Aquaculture Skill Development Centre, Visakhapatnam
11. **Sri Ch. Brahma Reddy**, Technical Officer, AU-Avanti Aquaculture Skill Development Centre, Visakhapatnam
12. **Dr. R. Prasad Naik**, Assistant Director, MPEDA, SRD, Visakhapatnam
13. **Miss. G.Suneena**, Quality Control, MPEDA, SRD, Visakhapatnam
14. **Sri Hari Prasad**, Engineer, Snowman Cold Storage Unit, Visakhapatnam
15. **Sri G.A.B. Nandaji**, Assistant Food Controller, FSSAI, Visakhapatnam

Editorial Committee:

1. **Prof. P. Janakiram,** Head of the Department, MLR Department, Andhra University, Visakhapatnam
2. **Dr. B. Madhusudana Rao**, Principal Scientist, ICAR-CIFT, Visakhapatnam Research Centre
3. **Dr. A. K. Reddy, Director,** AU- Avanti Aquaculture Skill Development Centre, Visakhapatnam
4. **Sri. Chidambar Nadiger,** COO, Avanti Frozen Foods Pvt. Limited
5. **Sri. B. Manmadha Rao,** Quality Assurance Manager, Sprint Exports
6. **Dr. Viji P.,** Senior Scientist, ICAR-CIFT, Visakhapatnam Research Centre
7. **Dr. Jesmi Debbarma,** Senior Scientist, ICAR-CIFT, Visakhapatnam Research Centre
8. **Dr. K. Ahamed Bhasha,** Scientist, ICAR-CIFT, Visakhapatnam Research Centre
9. **Sri. S. Mohanty,** General Manager, Avanti Feeds Limited
10. **Dr. K. Phani Prakash,** Administrator, AU-Avanti Aquaculture Skill Development Centre, Visakhapatnam
11. **Dr. D. Sunil Kumar,** Research Scientist, AU-Avanti Aquaculture Skill Development Centre, Visakhapatnam
12. **Sri Ch. Brahma Reddy,** Technical Officer, AU-Avanti Aquaculture Skill Development Centre, Visakhapatnam

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10 Food Safety for Ensuring Production of Safe Shrimp Products

Madhusudana Rao, B. and Jesmi Debbarma

Visakhapatnam Research Centre of ICAR-Central Institute of Fisheries Technology (ICAR-CIFT)

1. Food Safety

Food safety means that the food produced / processed is safe for human consumption. Hazard is any biological, chemical or physical agent that may cause an unacceptable health risk to consumers if present in the product. Safe food means that the food is free from biological hazards (eg. harmful bacteria such as *Salmonella*, *Listeria monocytogenes*, *Vibrio cholerae,* Viruses, worms, protozoa etc.), chemical hazards (harmful chemicals such as antibiotic residues, pesticides, heavy metals, dyes, cleaning compounds, food colours and additives other than permitted ones etc.) and physical hazards (foreign objects such as metal pieces, bolts, nuts, glass pieces, filth etc.). Globally, unsafe food is responsible for illness in 60 crore people and results in 4.2 lakh deaths, annually. Consumption of unsafe food causes digestive tract infections and cancers. In economic terms, unsafe food costs about 95 billion US dollars to low- and middle-income countries. The export of unsafe food leads to trade disruptions with substantial economic losses.

Ensuring safety of shrimp products is a complex process that starts from the shrimp farms and extends up to the shrimp consumer's home. The responsibility of ensuring food safety lies with all the people involved in shrimp farming (hatchery operators, shrimp farmers, shrimp feed manufacturers, fishermen), shrimp processing (processing unit management, shrimp processing workers, quality control personnel, transporters, traders) and shrimp consumption (consumers, retailers, food safety personnel).

Worldwide, consumers insist that the shrimp they eat is safe for eating. Food safety regulations have been developed by all countries to ensure that the shrimp that is available for human consumption is safe to eat. Non-compliance to standards leads to import refusals, detention, or destruction at the entry points of the importing country. Unsafe shrimp i.e., shrimp containing biological, chemical or physical hazards is not permitted to be sold in the markets. Some of the significant food safety concerns leading to import rejections are pathogens, parasites, marine toxins, decomposition, environmental contaminations, food and colour additives, foreign objects, and residues of veterinary drugs like antibiotics. Few consignments of frozen shrimp exported from India were rejected by the European Union, USA and Japan as they were found to be unsafe due to the presence of antibiotic residues. Some consignments of frozen shrimp were rejected due to the presence of Salmonella bacteria. Microbiological causes dominated the rejections by USA, while, chemical was the major cause for rejections at EU and Japan. The shrimp that are exported are tested for the presence of metal pieces (physical hazard) using a metal detector instrument in the packaging line. The chemical and biological hazards are analysed either in the in-house laboratory or Export Inspection Council (EIC) approved external laboratories. Only those shrimp products that meet the food safety regulatory requirements of the importing country are considered as fit for export and a 'Health Certificate' is issued by the Export Inspection Agency (EIA). The importing countries regularly check the shrimp consignments to ensure that the shrimp meet the food safety requirements specific to their country and reject all the shrimp consignments that do not meet their regulations.

The food safety regulations for export of shrimp from India are governed by the Export Inspection Council of India [Order S.O. 729 (E), dated 21 Aug, 1995 subsequently amended vide orders 792(E), 722(E), 464(E), 1227(E) (EIC, 1995). However, if specific food safety standards are prescribed by the importing countries, then the standards of the importing countries must be invariably followed (The food safety criteria for exporting shrimp to different countries are covered in a different chapter and hence are not included here).

However, for the benefit of the reader the food safety regulations pertaining to sale of shrimp products in the domestic market are included. Shrimp products that are meant for sale in India for human consumption are governed by the Food Safety and Standards Regulations (FSSR) of the Food Safety and Standards Authority of India (FSSAI), Government of India. Different set of standards were stipulated by the FSSAI for raw-frozen shrimp products (Table 1), cooked-frozen shrimp products (Table 2), battered and breaded shrimp products (Table 3) etc. The chemical hazard parameters for shrimp products are listed in Table 4

Table 1. Microbiological Requirements for Raw-Frozen Crustaceans (FSSAI, 2017)

	Sampling Plan		Limits (cfu/g)		Action in case of Unsatisfactory results
Hygiene Indicator Organisms	n	c	m	M	Improvement in hygiene; Time-Temperature Control along value chain
Aerobic Plate Count (cfu /g)	5	3	$1x10^6$	$1x10^7$	
Safety Indicator Organisms					
Escherichia coli	5	3	11 MPN/g	500 MPN/g	
Salmonella	5	0	Absent/25g		
Vibrio cholerae (O1 and O139)	5	0	Absent/25g		

Where, n: Number of units comprising the sample

c: Maximum allowable number of defective sample units

m: Acceptable level in a sample M: Specified level when exceeded in one or more samples would cause the lot to be rejected

Table 2. Microbiological Requirements for Cooked-Frozen Crustaceans (FSSAI, 2017)

	Sampling Plan		Limits (cfu/g)		Action in case of Unsatisfactory results
Hygiene Indicator Organisms	n	c	m	M	Improvement in hygiene; Time-Temperature Control along value chain
Aerobic Plate Count (cfu/g)	5	2	$1x10^5$	$1x10^6$	
Coagulase positive Staphylococci (cfu/g)	5	2	$1x10^2$	$1x10^3$	
Safety Indicator Organisms					
Escherichia coli	5	2	1 MPN/g	10 MPN/g	
Salmonella	5	0	Absent/25g		
Vibrio cholerae (O1 and O139)	5	0	Absent/25g		
Listeria monocytogenes	5	0	Absent/25g		

Table 3. Microbiological Requirements for Battered and Breaded shrimp products (FSSAI, 2017)

	Sampling Plan		Limits (cfu/g)		Action in case of Unsatisfactory results
Hygiene Indicator Organisms	n	c	m	M	Improvement in hygiene; Time-Temperature Control along value chain
Aerobic Plate Count (cfu/g)	5	2	$1x10^5$	$1x10^7$	
Coagulase positive Staphylococci (cfu/g)	5	1	$1x10^2$	$1x10^3$	
Yeast and Mold count	5	0	100		
Safety Indicator Organisms					
Escherichia coli	5	2	11 MPN/g	500 MPN/g	
Salmonella	5	0	Absent/25g		
Vibrio cholerae (O1 and O139)	5	0	Absent/25g		
Listeria monocytogenes	5	0	Absent/25g		

Table 4. Chemical hazard limits in farmed shrimp / crustaceans (FSSAI, 2011)

Chemical hazard	Maximum Residue limit (MRL)
Antibiotics	
Tetracycline	0.1 ppm
Oxytetracycline	0.1 ppm
Trimethoprim	0.05 ppm
Oxalinic Acid	0.3 ppm
Chloramphenicol	Below MRPL*
Nitrofurans (metabolites)	Below MRPL
Heavy metals	
Lead	0.5 ppm
Arsenic	76 ppm
Cadmium	0.5 ppm
Mercury	0.5 ppm
Methyl mercury	0.25 ppm
Chromium	12 ppm

* Minimum Required Performance Limit (MRPL)

Farmed shrimp are susceptible to viral, bacterial, fungal and parasitic diseases due to their relatively weak immune system. Antibiotics are used in aquaculture to treat the bacterial diseases. Improper use of antibiotics leads to the accumulation of antibiotics or their metabolites in the shrimp meat. Consumption of shrimp containing antibiotic residues or antibiotic metabolites causes health problems to the shrimp consumers. Consumption of shrimp meat containing chloramphenicol causes aplastic anaemia, consumption of shrimp meat containing nitrofurans and their metabolites causes cancers and consumption of shrimp meat containing sulphonamides and β-lactam antibiotic causes allergic reactions. Another problem with the improper use of antibiotics in aquaculture is the development of antimicrobial resistance (AMR) in bacteria. AMR bacteria are resistant to different antibiotics and therefore it is difficult to treat infections caused by AMR bacteria. The shrimp products are tested for the presence of antibiotics such as Chloramphenicol, Nitrofuran parent compounds (furazolidone, furaltadone, nitrofurantoin, nitrofurazone), Nitrofuran metabolites (AOZ, AMOZ, AHD, SEM), tetracycline

(oxytetracycline, tetracycline, chlortetracycline), sulfonamides, quinolones, fluoroquinolones etc.

Framed shrimp that are exported to certain countries must be tested for the presence of shrimp pathogenic viruses namely Yellow Head Virus (YHV), White Spot Syndrome Virus (WSSV) and Infectious Hypodermal and Haemopoietic Necrosis virus (IHHNV). These viruses are not harmful to human beings but the shrimp products must be tested for the presence of these viruses to prevent the entry of these shrimp pathogenic viruses into the importing country.

2. Good Manufacturing Practices (GMP) in shrimp processing units

GMP is one of the pre-requisites for implementing Hazard Analysis Critical Control Point (HACCP) management system in any food processing unit. Those procedures for a particular manufacturing operation which practitioners of, and experts in that operation consider to be the best available using current knowledge. GMPs are practices that are required in a processing unit to manufacture a product that meets the recommended national and international regulatory requirements in terms of quality of that specific product. Keeping the food production facility in good condition, keeping the equipment calibrated and in good running condition and employing a reliable and reproducible production process are some examples of GMPs. GMP is also referred to as Current Good Manufacturing Practices (cGMP) in some countries i.e., to emphasize the need to employ the up-to-date / up-graded technologies and systems to meet the quality requirements.

Processing of shrimp in processing units can potentially introduce food safety hazards that not only affects the consumer health but also leads to loss in economic value. Most of the food safety issues arise due to the presence of pathogenic microorganisms and harmful chemical contaminants. The shrimp processing unit must employ good manufacturing process in the form of proper design and maintenance of equipment and food contact surfaces.

2.1. Food Contact Surfaces: These are the surfaces that come in contact with human food during the normal course of operation. Example of food contact surfaces are tables, knives, cutting boards, crates, utensils, fish boxes, conveyor belts, ice storage bins, gloves etc. All the food contact surfaces should be adequately and routinely cleaned and disinfected.

2.2. Design and construction of the processing equipment: Easy to clean equipment is crucial for ensuring clean food contact surface. Processing equipment such as freezers, hardeners, cookers, etc., should not have sharp edges, crevices or angles to prevent the accumulation of dirt and food particles. Accumulation of food particles and water leads to bacterial growth and biofilm formation leading to contamination. Power cables related to the equipment should not hang loosely and must be protected in a closed casing. Adequate space should be available around the equipment for cleaning and sanitizing works. Insufficient aisle space results in accumulation of dirt and restricts workers movement.

The seven basic principles of hygienic design of food processing equipment

- All food contact surfaces must be inert and must not migrate to or be absorbed by the food.
- All food contact surfaces must be smooth and non-porous so that tiny particles of food, bacteria or insect eggs are not caught in microscopic surface crevices
- All food contact surfaces must be visible for inspection or the equipment must be readily disassembled for infection
- All food contact surfaces must be readily accessible for manual cleaning or readily disassembled for manual cleaning. If clean-in-place techniques is used then the hygiene results should be checked for effectiveness
- The equipment should preferably be self-emptying or self-draining
- Equipment must be designed so as to protect the contents from external contamination
- The exterior or non-food contact surfaces should be arranged to prevent harbouring of soil, bacteria or pests on the equipment itself as well as its contact with floors, walls, hanging supports and other equipment.

2.3. Cleaning of food contact surfaces: The different types of residues in food plants.

- Organic matter such as protein, fat and carbohydrate. These are most effectively removed by strong alkaline detergents (Caustic soda, NaOH)

- Inorganic matter such as salts of calcium and other minerals. These are effectively removed by an acid cleaning agent
- Biofilms, formed by bacteria, molds, yeasts and algae. These can be removed by strong alkaline detergents.

Biofilms occur when bacteria form a slime layer upon a food contact surface and provide an environment for pathogens to proliferate and also resist the action of disinfectants. The adhesion of pathogenic bacteria to a biofilm is a food safety hazard because the biofilm may detach and become a potential food safety hazard. Scrubbing the contact surface during cleaning detaches the biofilm. Therefore, adequate cleaning prior to sanitizing the food contact surfaces is paramount to control the biofilm problem.

Niche environment are sites within the food-processing plant where bacteria accumulate, multiply and contaminate the processed food. These sites are usually difficult to reach and clean during the normal cleaning and sanitizing procedure. Eg. Conveyor belts, rollers of conveyors, worn or cracked portions of the equipment, valves, switches. Processors must identify the niche areas and eliminate them. Microbiological sampling of the equipment helps to identify the niche areas. Purchase of easy to clean equipment and regular maintenance of equipment is necessary to avoid potential niches.

2.4. Disinfection: Disinfection is a procedure used in shrimp processing units to ensure a microbiologically acceptable standard of hygiene. These procedures rarely introduce 'sterility' which is the total absence of viable microorganisms. Disinfectants are the agents used for disinfection. Eg. Chlorine, iodophores, quaternary ammonium compounds, ozone, chlorine dioxide, hydrogen peroxide, UV irradiation, hot water (77-88 ^{o}C). Chlorine is one of the most widely used disinfectant. It dissolves in water and produces hypochlorous acid (HOCl) which is responsible for the disinfection activity through oxidation process.

2.5. Procedure for cleaning of processing machinery / equipment

- Dismantle the equipment and expose the surfaces to be cleaned
- Cover sensitive parts to protect them against water
- Clean the area, machines and equipment of food residues by flushing with water and by using brushes
- Apply the cleaning agent and use mechanical energy (Eg. Pressure or brushes)
- Rinse thoroughly with water to completely remove the cleaning agent after the appropriate contact time
- Disinfect with chemical disinfectants or heat
- Rinse the disinfectant chemicals off with water after the appropriate contact time
- After the final rinse, reassemble equipment and allow to dry

GMPs also deal with the condition of the premises and availability of water, ice, condition of water treatment system, effluent treatment system, sanitary facilities and installations.

3. Good Hygiene Practices (GHP) / Sanitation Standard Operating Procedure (SSOP)

GHPs mean all practices regarding the conditions and measures necessary to ensure the safety of food at all stages of the food chain. Sanitation Standard Operating Procedures (SSOP) are the documented practices for hygiene and sanitation required to meet the regulatory requirements for food control. SSOP are equivalent to GHP. Food processors are required to have key sanitary conditions written into SSOP. The written SSOP plan should explain the sanitary concerns, controls, in-plant procedures and monitoring requirements. SSOP plan demonstrates commitment to buyers and inspectors. SSOP plan ensures that management to production workers understands the basics of sanitation. The SSOP verifications are to be regularly performed on a daily basis. This prerequisite program requires that employees be trained in food safety practices and that wholesome fishery products are produced under sanitary conditions.

Eight Key sanitation conditions and practices in shrimp processing units

1. Safety of water and ice
2. Condition and cleanliness of food-contact surfaces
3. Prevention of cross-contamination from unsanitary objects
4. Maintenance of hand-washing, hand-sanitizing and toilet facilities for personal hygiene

5. Protection of food and food contact surfaces from adulteration
6. Proper labeling, storage and use of toxic compounds
7. Control of employee health conditions
8. Exclusion of pests

The water used in shrimp processing plants must be of potable quality and meet the water standards (IS: 4251 for non-EU processing units and EU Directive 2020/2184 for EU processing units; Note: Old Directive 98/83/EC is no longer in force). Water treatment units with softeners, filters, reverse osmosis membranes, coupled with chlorine dozers, ultraviolet (UV) light treatment are used to ensure that safe water is used for shrimp processing. The raw water lines and treated water lines are coded in different colours. Only treated water is used in the processing plant for washing the shrimp and ice manufacture. Proper plumbing is necessary to prevent backflow of post-process or wastewater. All the hose connections must be fitted with non-return valves (NRVs) and hose pipes should be kept off the floors.

All the shrimp contact surfaces should be kept clean and sanitized. The food contact surfaces in shrimp processing unit include pre-processing tables, processing tables, cutting boards, knives, conveyor belts, utensils, freezing pans, soaking bins, baskets, crates, etc. Uniform worn by the workers should be clean. Proper washing of the food contact surfaces should include scrubbing to remove biofilms and solid waste, cleaning with detergent, rinsing with potable water, application of sanitizer followed by final wash with potable water.

Cross-contamination occurs due to crisscrossing or mixing of cleaned food with raw, unwashed food. This can be prevented by ensuring unidirectional flow of men and material in the shrimp processing unit. The raw and cooked products should be kept separate at all times; the unprocessed material must be maintained at a temperature as close of that of melting ice (less than $4^{o}C$) to avoid multiplication of bacteria.

The shrimp processing unit must have a clear health policy in place that restricts the entry of sick employees as they can potentially act as carriers or transmitters of pathogenic microorganisms either directly through their bodies or indirectly through their clothing. Workers who are sick or carrying open wounds must be excluded from handling and packaging the shrimp in the processing unit. Workers suffering from gastrointestinal (diarrohea, vomiting) and respiratory (coughing, running nose) infections must not handle the food. Non-contact temperature screening of the workers for detecting higher body temperature at the point of entry into the processing unit must be the first step to screen workers regarding their health status. This has become a more common practice in processing plants during the COVID-19 pandemic to assess the health of the employees. The screening should be extended not only to the employees but also to the visitors (e.g. buyers, suppliers, auditors) entering the shrimp processing unit premises. Records have to be maintained on a daily basis. The workers should remove their jewellery and footwear. They should change their street clothes with a clean uniform in the specific change room. The workers should wear gum boots, cover the hair with caps/covers, cover their nose and mouth with masks prior to their entry into the shrimp processing area. Workers must not carry allergens in to the processing plant. Workers should not eat in the processing area. The eating should be restricted to designated area (canteens/ lunch room) constructed in non-production areas. Smoking, chewing of tobacco products and spitting must be prohibited in shrimp processing units. The workers should be provided with individual locker facility in the change rooms to store their personal items like mobiles, jewellery, wrist watches etc. Workers must be vaccinated and undergo regular medical check-ups. Workers should wash their hand properly for a minimum of 30 seconds as per WHO washing guideline. Hand sanitizers should be prepared with the prescribed concentration (chlorine hand dip of 50 ppm). Hand washing facility to be provided in the change rooms located near entrances of processing rooms and in rest rooms.

Dirty hands are major vehicle for transfer of bacteria. It is of utmost importance from the food safety point of view to train the workers on proper hand washing procedure. However, as the bacteria are invisible to the naked eye, the workers do not realize that they carry bacteria on their hands and washing their hands reduces the bacterial loads. Palm impression technique developed by CIFT is a simple participatory method that helps in creating awareness on hand hygiene among the illiterate or less educated workers. In this method workers place unclean hand (palm) on a large size petri plate containing nutrient agar. The same worker is then asked to wash his/her hand properly with soap and

water and after drying place his/her palm on another nutrient agar petri plate. After overnight incubation, the petri plate on which the unclean palm was placed will appear as full of bacterial colonies where the petri plate on which the clean palm was placed shows very few bacterial colonies. By conducting this type of exercise involving the workers, help in educating them on the need to wash and sanitize their hands. The cleanliness of the hand needs to be checked regularly by swabbing 25 cm^2 of worker's hand. A clean hand has a bacterial load of less than 100 bacteria per square centimetre.

The workers, after washing their hands, should avoid touching potentially dirty items. The plant should have foot operated taps/ automatic water dispensers, single use paper towels, foot operated trash bins. The workers should know that they should always wash their hands before the start of the work, after using the toilet and before restart of work after lunch break etc. The toilet facilities should be clean and in good repair. Hand driers or disposable towels to be provided for drying the hands after washing and foot operated bins to be provided for disposing the used towels. The processed shrimp and packaging material should be protected from condensate or other dripping liquids and from splashes of water. The air temperature in the pre-processing and processing areas should preferably be controlled through air-conditioners to avoid sweating by the food workers. Dipping sweat is a source of unwanted microorganisms and must be avoided as far as possible during handling of food.

Food, food contact surfaces and food packaging material must be protected from adulterants. Potential sources include water splashing from the floor, condensate from air conditioners, refrigerator condensers, pipes, light fixtures and ceilings, toxic substances (eg. pesticides, fuel, cleaning compounds and sanitizing agents), filth and physical contaminants (eg. Glass, metal fragments, dirt or corrosion from fans and other fixtures) and airborne allergen dust. Processors and food handlers need to be aware of all avenues that could cause the food to be adulterated. The maintenance department needs to establish a regular maintenance programme for the facility's ventilation system to avoid formation of condensation. Floors must be maintained in good order to avoid formation of pools of water and supervisors must ensure that no floor splash occurs during processing or when food is exposed. Only food grade lubricants should be used on all moving machinery parts that come into direct contact with food. Only approved chemicals for cleaning, disinfection, pesticides and rodenticides should be used in the processing plant.

Label and store toxic compounds properly. All chemical products such as detergents, pesticides should be labelled properly and stored separately. Toxic compounds must be stored in a secured area with limited access separated from food processing areas and areas where food and packaging materials are stored.

Pests such as insects and rodents carry disease causing organisms. Moreover, their droppings contaminate the food. Pests have to be controlled both within the processing plants and around the processing plant. Bait stations or glue traps at different points are needed to trap the rodents. The doors and windows should be tightly fit. All entrance and exit points to be fitted with air curtains and plastic strip curtains.

Biological hazards (bacteria, viruses etc.) in a shrimp processing unit are controlled through time / temperature controls, heat and cooking, cooling and freezing, or other processing techniques. Chemical hazards (natural toxins, pesticides, drug residues, unapproved food and color additives, etc.) are mainly controlled through source controls (e.g., vendor certification and raw material testing), time/temperature controls, production controls (e.g., proper use and application of food additives) and labeling controls. Physical hazards (metal, glass) are controlled through source controls and production controls (metal detectors).

Food safety regulations are not fixed. The food safety regulations change with the emergence of new pathogens, new harmful chemicals, development of sensitive instruments to detect the extremely low quantities of hazards. For example, the COVID 19 pandemic has introduced new regulations to control virus transmission through food and food packaging which were not followed previously. It is pertinent to always keep in mind the production of safe food is the ultimate objective of any food processing establishment because if it is not safe, it is not food.