



P-ISSN: 2349-8528

E-ISSN: 2321-4902

www.chemijournal.com

IJCS 2020; 8(1): 358-368

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Received: 04-01-2020

Accepted: 08-02-2020

Sahil Kamboj

Division of Food Science and
Technology, SKUAST-J,
Chatha, Punjab, India

Neeraj Gupta

Division of Food Science and
Technology, SKUAST-J,
Chatha, Punjab, India

Julie D Bandral

Division of Food Science and
Technology, SKUAST-J,
Chatha, Punjab, India

Garima Gandotra

Division of Food Science and
Technology, SKUAST-J,
Chatha, Punjab, India

Nadira Anjum

Division of Food Science and
Technology, SKUAST-J,
Chatha, Punjab, India

Corresponding Author:

Sahil Kamboj

Division of Food Science and
Technology, SKUAST-J,
Chatha, Punjab, India

Food safety and hygiene: A review

Sahil Kamboj, Neeraj Gupta, Julie D Bandral, Garima Gandotra and Nadira Anjum

DOI: <https://doi.org/10.22271/chemi.2020.v8.i2f.8794>

Abstract

Food hygiene are the conditions and measures necessary to certify the safety of food from production to consumption. Food can become contaminated at any point during slaughtering or harvesting, processing, storage, distribution, transportation and preparation. WHO (1984) has defined food hygiene as all conditions and measures that are required during production, processing, storage, distribution and preparation of food to ensure that it is safe, wholesome and fit for human consumption. Lack of requisite food hygiene can lead to foodborne diseases and death of the consumer. Foodborne illness has been associated with improper storage or reheating (50%), food stored inappropriately (45%) and cross-contamination (39%). The increased numbers of people eating out have caused the emergence of food borne illness due to unhygienic preparation and lack of knowledge of personal hygiene. These contributory factors are due to a lack of food hygiene awareness or implementation. Hazard analysis and critical control points, or HACCP is a systematic preventive approach to food safety from biological, chemical, and physical hazards in production processes that can cause the finished product to be unsafe and designs measures to reduce these risks to a safe level. The Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) require mandatory HACCP programs for juice and meat as an effective approach to food safety and protecting public health. Food hygiene training is therefore crucial in food safety and is an essential part of the hazard analysis critical control point (HACCP) concept. Food hygiene and safety usually refer to contamination with 'microorganisms' or 'microbes'. All over the world people are seriously affected every day by diseases that are caused by consuming unhygienic and unsafe food. Good hygienic practices (GHP) to prevent and control foodborne diseases. Foodborne diseases result from eating foods that contain infectious or toxic substances. The term 'food hygiene' refers particularly to the practices that prevent microbial contamination of food at all points along the chain from farm to table. Food safety is a closely related but broader concept that means food is free from all possible contaminants and hazards. In practice both terms may be used interchangeably. HACCP implementation in a food business requires the recognition of hazards and their control. Therefore, a major challenge in the food industry is to motivate food handlers to apply what they have learnt regarding food hygiene.

Keywords: Food hygiene, safety, foodborne disease, HACCP, GHP, food quality

Introduction

Food hygiene is the conditions and measures necessary to ensure the safety of food from production to consumption. It is a fundamental requirement of any food process that the food produced should be safe for consumption. Food safety is a basic need but there is a danger that it may be overlooked in the development of effective and efficient processes. Food safety remains a critical issue with outbreaks of foodborne illness resulting in substantial costs to individuals, the food industry and the economy (Kafarstein, Motarjemi, & Bettcher, 1997) [29]. Within England and Wales the number of food poisoning notifications rose steadily from approximately 15,000 cases in the early 1980s to a peak of over 60,000 cases in 1996 (Wheeler *et al.*, 1999) [50]. Unsafe food has been a human health problem since history was first recorded, and many food safety problems encountered today are not new. Although governments all over the world are doing their best to improve the safety of the food supply, the occurrence of food-borne disease remains a significant health issue in both developed and developing countries. Food can become contaminated at any point during slaughtering or harvesting, processing, storage, distribution, transportation and preparation. Proper food preparation can prevent most food borne diseases (Five keys to safer food manual). More than 200 known diseases are transmitted through food. (Mead *et al.*, 1985) [44]. Recent years have seen a reversal in this trend but food poisoning remains a high priority for the public and government (Parliamentary

Office of Science & Technology, 2003). Mishandling of food plays a significant role in the occurrence of foodborne illness. Improper food handling may be implicated in 97% of all foodborne illness associated with catering outlets (Howes, McEwen, GriYths, & Harris, 1996) [26].

The chances of food contamination and cross contamination become higher especially in the lower socio-economic classes due to unsatisfactory environmental conditions, poor personal hygiene, poor quality and insufficient water supplies, unhygienic preparation storage and feeding of foods. (Khan Hameed, 1997; UNICEF, 2000) [30,47]. Food safety hazards are contaminants that may cause a food product to be unsafe for production. Lack of adequate food hygiene can lead to food borne diseases and death of the consumer. Contaminated food presents one of the most common cause and major contributor to gastrointestinal illness (e.g. acute diarrhea, nausea, vomiting and abdominal pain), compromised nutritional status and less resistance to disease and loss of productivity in the world today (Jacob, 1989) [27]. To a large extent gastrointestinal illness resulting from food contamination can be prevented if safe food-hygiene practices are followed at various stages of food purchase, storage, preparation and consumption (Mathee *et al.*, 2004) [35].

The World Health Organization (WHO) has long been aware of the need to educate food handlers about their responsibilities for food safety. In the early 1990s, WHO developed the Ten Golden Rules for Safe Food Preparation and introduced the

Five Keys to Safer Food in 2001. Recognizing the importance of safe food in human health WHO has selected the theme of Food Safety for the World Health Day 2015 with the objective of ensuring safety of food from farm to plate (Subba Rao GM *et al.*, 2007) [46].

Food contamination during food processing

The food processing steps are shown in (Fig 1) The presence of unwanted materials such as dust and particles during the manufacturing and transportation time is called contamination. The term contaminants include any unwanted matter that is found in the product. These contaminants affect the quality of the product or the process. It has been demonstrated that food contamination, either from microbiological or chemical origin, is the highest concern for consumers. Sample treatment devices, such as micro extraction techniques able to remove the matrix interferences and to concentrate the analyses from the sample, have been developed and proposed as powerful tools for food analysis. But the task of identifying the contaminants, either those coming from the food production, the food processing or the packaging is still a challenge. The information about the likely contaminants coming from each step of the food processing is essential. In the following paragraphs the description of the main contaminants in each step, how to control them and how to prevent or diminish them from the food are discussed. This information is essential to identify the origin of the contaminants in the final food.

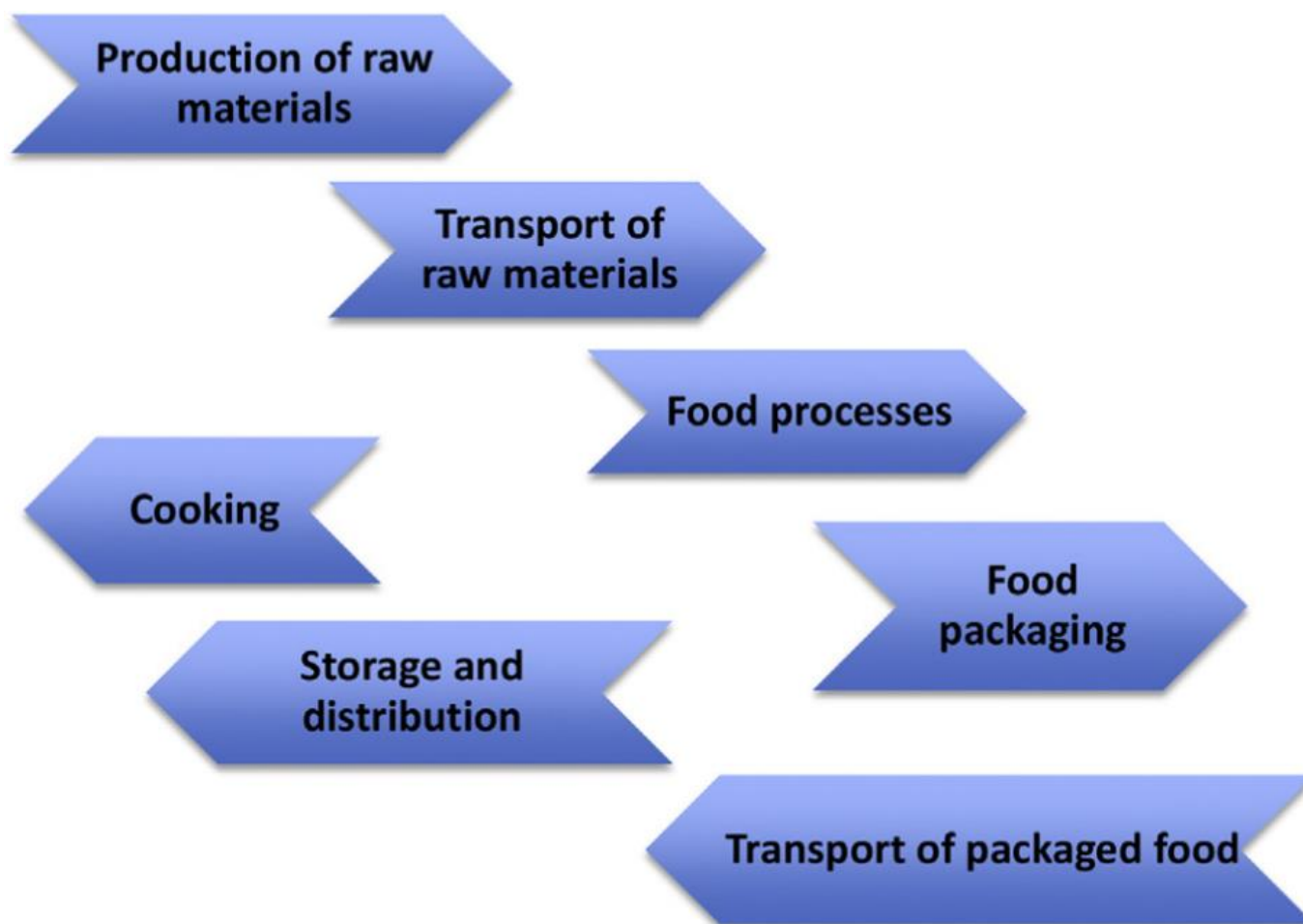


Fig 1: Steps of Food Processing

1. External raw food contamination

Industrial growth, advances in the use of agrochemicals, or the urban activities can contribute to the presence of food

contaminants. An important focus of food contaminants is the use of fertilizers and pesticides, since they can cause health problems if they are consumed by humans. Some studies

detected pesticide residues in fruits and vegetables (Kobayashi, Otsuka, & Tamura, 2011) ^[31] and also some derivatives with also adverse effects, such as metabolites from organochlorine pesticides have been found in fatty food (Chung & Chen, 2011) ^[12]. Heavy metals such as cadmium, lead, mercury, and arsenic, recognized as toxic (ATSRD, 2011) ^[1], can be present in air, soil, and water (Zukowska & Biziuk, 2008) ^[52] and therefore they can be transferred to foodstuff. The analysis of heavy metals has been performed in several foodstuffs such as honey, spinach, potatoes, fish and tea. The major techniques employed for heavy metal analysis are flame atomic absorption spectrometry (FAAS), graphite furnace atomic absorption spectrometry (GFAAS), cold vapor atomic absorption spectrometry (CVAAS), inductively coupled plasma atomic emission spectrometry (ICP-AES), and inductively coupled plasma mass spectrometry (ICP-MS). Several methods have been developed for determining antibiotic residues in foodstuff such as meat, eggs (Donkor, Newman, & Tay, 2011) ^[19] or milk, such as using the microbial inhibition plate test (Koenen-Dierick *et al.*, 1995) ^[32] or by liquid chromatography methods (Freitas, Paim, & Silva, 2014) ^[23].

2. Contamination during food transport

Food contamination can also take place during transportation. It can be caused by from vehicle exhausts of petrol and diesel or because of a cross contamination in the vehicle used for food transportation. This cross-contamination can create a serious risk for food safety. In 1999, a major illness in the European Economic Community was attributed to fungicide-contaminated pallets used for transportation and storage of food packaging materials. Long distance transport ship has been also several times affected by cross contamination from chemicals used for disinfection or from other sources (Nerín, Canellas, Romero, & Rodríguez, 2007) ^[41]. The study carried out by (Nerín *et al.*, 2007) ^[42] is a good example of the contamination of food by permeation of naphthalene, methyl bromide, toluene, ethyl benzene and ortho par a xylenes through a theoretical high barrier material.

3. Contamination caused by cleaning processes

Cleaning and disinfecting during food processing eliminate the presence of possible microorganisms and therefore, they are crucial to reduce food contamination. Chemicals used as cleaners or disinfectants must be appropriate for food contact surfaces and need to be accepted by the legislation. Products such as glass cleaners or some metal cleaners can't be used because they might leave unsafe residues. The addition of sanitizers in quantities far above permitted levels could leave some residual concentration on treated materials or food even in minimum processed fruits and vegetables, and therefore, to quantify the residual chemicals present in the food is important in order to certify that they have been completely removed. Some common surfactants are quaternary ammonium compounds such as dodecyl-trimethyl-ammoniumchloride and nonionic surfactants such as stearyl alcohol ethoxylate. Factors affecting its elimination from different materials surfaces, such as rinsing time or water temperature (Helmschrott & Wildbrett, 1985) ^[25]. These compounds are commonly analyzed by liquid chromatography mass spectrometry (Vidal, Vega, Lopez, & Frenich, 2004) (Li & Brownawell, 2009) ^[48, 34]. Problems related to residues coming from cleaning agents and disinfectants used in surfaces of food handling equipment and its transference to food that has been in contact with such surfaces have been discussed by several authors (Naegeli & Kuepper, 2006) ^[38].

4. Contamination due to heating steps

The use of high cooking temperatures in combination with external factors, can lead to the formation of toxic compounds, which can have a deleterious effect on the food quality and safety. Certain toxic compounds (e.g., acrylamide, nitrosamines chloropropanols, furanes or PAHs) can be formed in foods during their processing, such as during heating, baking, roasting, grilling, canning, hydrolysis or fermentation. Frying is by far the cooking process that can act as a generator of a wide variety of toxic compounds into the food. Flavor substances are produced by reactions of oxidized frying oil with proteins and other sulfur and nitrogen substances in the food. Various compounds are released from the food into frying oil, enhancing discoloration or off-flavors. Pigments present in frying oil may also be adsorbed on the surface of fried food. A recent report from EFSA [13] says that the mean exposure to 3-monochloro-1,2-propanediol (3-MCPD) was <1 mg/kg b.w. per day in most population groups (EFSA, 2011) ^[20]. 3-MCPD can have other origins, it can be formed during the acid hydrolysis of wheat, soybean and other vegetable protein products (Johansson & Jägerstad, 1993) ^[28] and it can also migrate from epichlorohydrin resins used for humidity protection in paper and cellulose materials often employed for sausages casings. Acrylamide and its precursors are also important contaminants coming from heating processes. Certain processing contaminants, such as nitrosamines, can be formed by interaction of natural food components with food additives during heating. Nitrosodimethylamine has been detected in certain foods as a result of the direct-fire drying or roasting processes. Nitrosamine formation during vapor or boiling cookings (which implies lower temperatures, 100°C) are lower than the amount formed during frying, roasting or grill cooking. They can be measured by different methodologies, colorimetric and spectroscopic methods following gas or liquid chromatography or as a total N-nitroso group, by measurement of chemically released nitric oxide. Gas chromatography (GC) coupled to the specific thermal energy analyzer detector (TEA) is the most suitable, sensitive and widely used analytical method to detect volatile nitrosamines (Byun *et al.*, 2004). Other processing contaminants formed during heating include polycyclic aromatic hydrocarbons (PAHs), present in grilled and smoked products, ethyl carbamate and other products or furan derivatives present in a variety of heat-treated foods, especially coffee and canned/jarred food. Furan contributes to the off flavor of the food and can be formed from a variety of precursors, like ascorbic acid, carbohydrates degradation, amino acids degradation as well as oxidation of fatty acids. The production of mutagens is much lower in absence of fat. Model mixtures containing Maillard precursors such as glycine, glucose and creatinine were heated in contact with iron salts and fats. As result, substituted imidazoquinoxalines were identified among the mutagenic products (Freedman, 1999). The reaction was enhanced by oxidized fats and iron salts, and it was not inhibited by tocopherol. Some mutagenic activity of frying fats is also due to nitrogen-free lipid-hydroperoxide decomposition products and it is independent from the fried substrate. Microwave heating is becoming an increasingly used process for heating foodstuffs in home and in some industrial sectors. A common characteristic of the microwaving cooking is that the food is cooked in the packaging material (wrapping film, container) in the microwave oven (Nerín, Fernandez, Domeno, Salafranca, 2003). Such microwavable packaging materials include plastics, paperboard and composites, which during microwave cooking many of their components (i.e.,

plasticizers, antioxidants, monomers, stabilizers, etc) can migrate from the package into the food. This results in a decrease of food quality and food safety (Ehlert, Beumer, & Groot, 2008) ^[21]. Microwaves can also increase the diffusion rates, cause degradation of migrants or polymer, or cause hot spots, which would increase the migration to higher levels than those expected from the bulk heating temperature (Nerin, Acosta, & Rubio, 2002) ^[39].

5. Food packaging

Food packaging provides many advantages such as physical protection, barrier protection and it also allows a better food preservation that will increase the shelf life of the product. The direct or indirect contact between the food and the packaging material can end up the transference of these substances from the packaging to food, in a phenomenon called migration (Catala & Gavara, 2002) ^[11]. Migrants can pose a health risk for consumers if they have a toxic effect. To protect the consumers, there is a strict legislation in FDA, Europe, Mercosur, Australia and Euroasia as well as in many countries to avoid the contamination from the materials and articles to the food in contact with them. In Europe, food packaging materials must comply with the framework Regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food (European-Commission, 2004) and with Regulation (EC) No 2023/2006 on good manufacturing practice (European-Commission, 2006). migration from plastic food contact materials must fulfill the Regulation EU/10/2011 from the European Commission (European-Commission, 2011). Any compound with a molecular mass lower than 1000 amu can migrate and cross the polymeric or paper layers, arrive at the food and be dissolved in it. When metallic cans are used for food packaging, corrosion phenomena in the metallic surface of the can could produce a migration of metallic ions to food, such as iron or tin (Buculei, Gutt, Sonia, Adriana, & Constantinescu, 2012) ^[8]. Minor by-products from the manufacture of epoxy resins, such as bisphenol A, bisphenol A diglycidyl ether (BADGE) or cyclo-di- BADGE among others can migrate to food (Cabado *et al.*, 2008) ^[10]. Another common material used in marmalades, jams, vegetables, beans or sauces packaging is glass. In this case, migration comes from the metallic lids used for closing the glass jars. Epoxidized soybean oil (ESBO) is one of the additives used as plasticizer in PVC and its migration to food has been reported by several authors (Pedersen *et al.*, 2008). Paper and board are commonly used for packaging dry food, such as flour or sugar, or products such as rice, cereals or frozen food. Migration from paperboard additives or from printing inks to foodstuff can take place. The most recycled packaging material and the use of recycled materials can produce food contamination of substances such as mineral oils or plasticizers coming either from printing inks or adhesives (Nerin, Contin, & Asensio, 2007) ^[43]. Typical polymers used in food packaging materials are polyethylene (PE), high density polyethylene (HDPE), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS) and polycarbonate (PC). Migration from inks has been

also widely studied, specially migration of photo initiators such as benzophenone (BP) or 2-isopropylthioxanthone (ITX) coming from UV curable inks (Sanches-Silva *et al.*, 2009) ^[45]. More recently migration from components coming from printing inks as a result of set-off transference has been reported (Margarita Aznar, Domeno, Nerin, & Bosetti, 2015) ^[2]. Plastic recycled materials have also special relevance, as they could contain chemical compounds coming from the previously packaged food, substances resulting from the misuse of the packaging by the consumer or intrinsic contaminants from the recycling process (chemical additives) (Bayer, 2002) ^[4]. The substances intentionally added to food packaging materials, non-intentionally added substance (NIAS) can also migrate to food and can have also adverse effects. Degradation processes of the polymer itself due to high temperatures or high irradiation energies that take place during polymer manufacturing (Dabrowska, Borcz, & Nawrocki, 2003) ^[17], and also from degradation processes of polymer additives (Burman & Albertsson, 2005) ^[9]. NIAS can also come from impurities present in the raw materials.

6. Contamination during food storage

Food storage conditions are key parameters in food quality and safety. Proper storage extends the shelf life of food, which depends on the food type, packaging and storage conditions, particularly temperature and humidity. Organoleptic changes should not occur during food storage and therefore packaging materials used for long term storage should exhibit very good barrier properties. Moisture can lead to the breakdown of some packaging materials (e.g., paper degradation and metal rusting). The optimal range of temperature is the cool to moderate range, between 4 and 21°C. Direct sunlight can speed deterioration both on the food and on the packaging. Depending on the barrier properties the transference of compounds through the packaging material will be different as was demonstrated (Nerin *et al.*, 2007) ^[42].

Food safety hazard

Food safety hazards are contaminants that may cause a food product to be unsafe for production. Hazards are defined by Codex 1997^[22] as follows: "Hazard: a biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect". Hazards may enter a food product from its ingredients or may contaminate during processing or handling. It is important to understand the likely hazards that might be encountered in the chosen ingredient types, or that might be present in the processing environment. This allows the development team to identify the best ways to control these hazards, either by preventing their entry to the process, destroying them or reducing the contamination to a level. It is no longer process a food safety risk. This information on likely hazards and proposed control options should link with the prerequisite good manufacturing practice programs and HACCP systems to ensure everyday control is established in the manufacturing operation.

Table 1: Types of Hazard

	Type of hazard		
	Biological	Chemical	Physical
Considerations	Organisms that can cause harm through infection or intoxication	Chemicals that can cause harm through toxic effects, either immediate or long-term	Items that can cause harm through direct injury or choking
Examples	Pathogenic bacteria, e.g. <i>Escherichia coli</i> , <i>Bacillus cereus</i> , <i>Campylobacter jejuni</i> , <i>Clostridium botulinum</i> , <i>C. botulinum</i> (non-proteolytic), <i>C. perfringens</i> , <i>Salmonella</i> spp, <i>Shigella</i> spp, <i>Staphylococcus aureus</i> , <i>Vibrio parahaemolyticus</i> ; Viruses, Protozoan parasites, e.g. <i>Cryptosporidium parvum</i> , <i>Giardia intestinalis</i> ,	Mycotoxins, e.g. aflatoxins, patulin, vomitoxin, fumonisin; pesticides, allergenic materials, heavy metals, PCBs, dioxins, cleaning chemicals	Glass, metal, stones, wood, plastic, pests, intrinsic natural materials, e.g. bone, nut shell

Ways to maintain food safety and hygiene

1. Good Manufacturing Practices (GMP).
2. Sanitation Standard Operating Procedure (SSOP).
3. Good Hygiene Practices (GHP).
4. Hazard Analysis of Critical Control Points (HACCP).

1. Good manufacturing practices (GMP)

GMP have existed since the 1970s, but were formalized in different countries only in the mid-1990s (Bennet and Steed, 1999) [5]. GMP are actions applied to the production of food, drug, and medical equipment production. GMP are based upon four points: exclusion, removal of undesirable and foreign matter, inhibition, and destruction of undesirable microorganisms. The elements that make up GMP are: the facility and its surroundings, the staff, cleaning and sanitization processes; equipment and utensils; processes and controls; and storage and distribution. Analysis and control of these elements by the GMP program aim at the production of high-quality foodstuffs GMP are one of the ways to control foodborne diseases. Industries that have adopted GMP programs obtained the following results, among others: better quality of foodstuffs; safer products; decreased incidence of consumer complaints; better, more agreeable, cleaner and safer working environment; greater employee motivation and productivity; and improved psychological conditions (Cruz *et al.*, 2006) [15]. The implementation of GMPs is a continual process based upon the management of the PDCA (plan, do, check, and act) cycle. GMP implementation can be divided into four steps: performing the initial diagnosis; elaborating the roadmap; addressing non conformities; and reevaluating the corrective measures. Initial diagnosis and reevaluation of corrective measures are usually carried out by inspection of the facilities using a checklist based upon the GMP regulations of the country. Roadmaps can be generated after inspection, while the implementation of corrective measures often requires the decision on priority areas, depending upon the availability of resources and efforts in the company (Dias *et al.*, 2012) [18].

Periodic inspections performed by official agencies or company internal controls are able to determine these priority areas.

2. Sanitation standard operating procedure (SSOP)

SSOP are written procedures developed and implemented in a facility to prevent direct contamination or adulteration of the products. SSOP include a complete description of the specific activities required to maintain utensils and equipment free of pathogenic microorganisms and minimal deteriorating microbiota, preventing the contamination of foodstuffs that get in contact with these utensils and equipment (Cruz *et al.*, 2006) [15]. The facility is required to maintain these written procedures on file, and these must be available to regulating or government bodies upon request. The following central directives of SSOP have been determined considering the potential sources of contamination: cross-contamination from raw to cooked products (e.g., surface contact with contaminated foods); contact of product with nonpotable water (e.g., condensation on exposed products) or other unsafe substances; contact with nonfood substances (e.g., pesticides); contact with airborne substances; diseases or inadequate hygiene of handlers; foreign matter; and pest control. In a recent report by (Cunha *et al.*, 2015) [16], higher levels of stress and anxiety as well as lower knowledge scores on food-safety issues were found among food handlers who did not participate in food-safety trainings, suggesting that training is able to improve knowledge and possibly empower food handlers at the same time, increasing their self-efficacy and reducing anxiety and stress levels.

3. Good hygiene practices

Good hygiene practices (GHP) are the procedures and practices undertaken with the use of best practice principles (British Retail Consortium, 2011). European Commission (EC) Regulation No 852/2004, defines food hygiene as the measures and conditions necessary to control hazards and to ensure fitness for human consumption of a food stuff taking into

account its final use (EU, 2004). GHP are generally called the prerequisite measures upon which other Food Safety and Quality Management Systems are built. They include an exhaustive list of measures and among them is staff personal hygiene and training. Food hygiene training is a legislative requirement (Food Standards Agency, 2009) that ensures that safety practices are used and maintained in food preparation environment. lack of success in hygiene training were methods used, demographics of trainees and their preparedness to learn, lack of supervision after training, absence of refresher programmes and lack of resources to implement knowledge gained in areas with economic challenges (Gilling *et al*2001)^[24]. Feglo *et al.* (2004) recommended training and surveillance to be paramount in areas where due to cost, the establishment and designing of acceptable infrastructure and utilities could take ages to ensue. Feglo and Sakyi (2012) equally highlighted the importance of hygiene training in the food industry.

4. Hazard Analysis of Critical Control Points (HACCP)

It is a systematic set of activities used to control food production in order to ensure food safety and prevent changes in foodstuffs. The system is based upon the use of control practices in given production steps where there is a greater probability of occurrence of health hazards. The prerequisite programs for HACCP implementation in food industries are GMP and SSOP, which involve several aspects of the food industry, such as physical structure and maintenance, water supply, personal hygiene, pest control, sanitization techniques and equipment, calibration of instruments, and quality control of raw material and ingredients, among others (Barendz, 1998). Prerequisite Programs (PRPs) provide a hygienic foundation for the HACCP system (NACMCF, 1997) by enabling environmental conditions that are favorable for the production of safe food (CFIA, 1998). the system is applied to all steps of the food chain, from the production of raw material to the final product, including aspects related to consumer demands, such as processed products that do not have negative effects on their

health (World Health Organization, 1997)^[51]. Key milestones included the publication of guidance by the International Commission on Microbial Specifications for Foods (ICMSF) in 1988 (ICMSF, 1988). The HACCP system uses predetermined concepts and terms that include, according to Bryan (1992)^[6].

- Hazard: Unacceptable biological, physical, or chemical contamination that renders food inadequate for consumption.
- Risk: Estimated probability of the occurrence of a hazard.
- Critical control point (CCP): Production step where preventive measures are applied in order to maintain the given product under control, and to eliminate, prevent, or reduce risks to the health of the consumer.
- Critical limit: Value or attribute determined for each variable related to a critical point. Noncompliance leads to risks to consumer health. Critical limits are determined by guidelines or legal standards, specialized literature, practical expertise, previous surveys, internal company regulations, and other sources.
- Corrective action: Immediate and specific actions to be put into place when noncompliance with critical limits occur.
- Validation: Use of supplementary tests or review of monitoring records to determine if the HACCP system is functioning according to the plan.
- Decision tree: Logical sequence used to determine if a raw material, ingredient, or process step is a CPP for a given hazard.

According to the World Health Organization (1997)^[51], there are seven basic principles that should be followed for HACCP implementation and the logic system for the application of HACCP, according to the *Codex Alimentarius* (Food and Agriculture Organization, 1997)^[22], has 12 steps that start before these seven principles and involve them as the implementation of the system progresses, as follows:

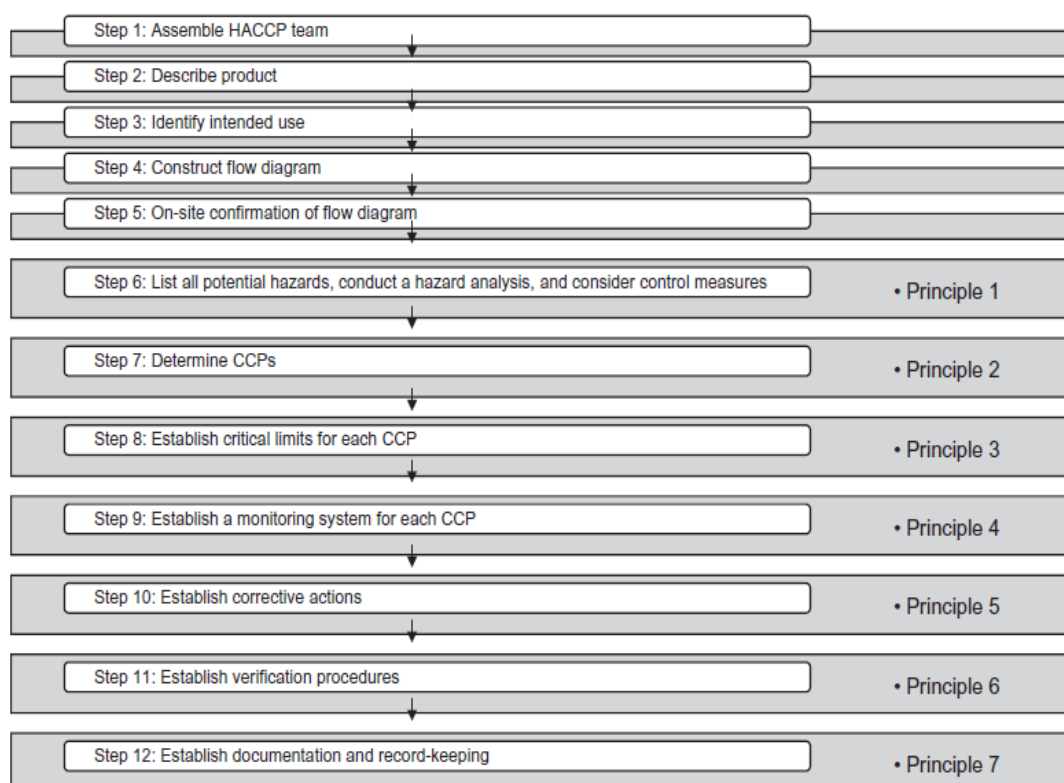


Fig 2: Steps of Hazard Analysis and Critical Control Points

1. Assemble the HACCP team

HACCP uses multidisciplinary teams to ensure that decisions about food safety hazards and their control are taken by people with the correct blend of knowledge, skills and experience to collectively understand the risks to consumer health and how these can be minimized. This multidisciplinary aspect of the HACCP team is believed to be one of the most powerful strengths of HACCP. The essential expertise within the HACCP team includes:

- Understanding of the process operations, ingredients, and products on site.
- Knowledge and experience of the equipment, how it works to achieve process conditions, and the likely failure modes.
- Understanding of the likely hazards and appropriate control mechanisms, including product design safety criteria, process controls, including how to validate all the necessary control requirements.
- Knowledge experience of HACCP principle and application.

HACCP team leader needs to be appointed and a scribe or administrator identified. For a HACCP team to work effectively, all team members need to understand the application of HACCP principles. For best results, the whole team should be trained using a practical training intervention that covers both theory and application of HACCP. It is important that the HACCP study process is guided by the team members with the best knowledge of HACCP Principles (Wallace *et al.*, 2012) [49].

2. Describe product/process

This step considers information both about the product(s) and the process and helps HACCP team members to understand the background to the operations. It forms a useful introduction to the HACCP plan and can also be used as a training tool for new personnel and briefing aid for internal or third-party auditors or regulatory inspectors.

The product/process description should include

- Main ingredient groups to be used or “work-in-progress” (WIP) inputs to process modules;
- Main processes and how materials are prepared/handled;
- Production environment and equipment layout;
- Hazard types to be considered, if known;
- Key control measures available through formulation, processes, and prerequisites;
- Packaging/wrapping if appropriate to scope of study;
- Safe product design characteristics.

In foodservice operations it is also normal practice to group all the different menu/food items into like process groups at this stage, as this will help in developing process flow diagrams.

3. Identify Intended Use

It include product abuse, for example, improper storage temperatures, or consumption of the product in different ways from those originally envisaged, for example, the consumption of raw cookie dough. Different consumer groups may have varying susceptibilities to the potential hazards, for example, the elderly, young children, or immune compromised individuals. It must be emphasized that all products should be

safe for all consumers. Intended use and consumer group information is usually included as part of the product and process description record (from step 2). In many cases it will be important to provide information to the consumer about how to handle, store, and prepare (including cooking, as appropriate) the food item safely and this can be derived once the intended use and potential misuse of the product are established.

4. Construct process flow diagrams

A process flow diagram outlines all the process activities in the operation being studied. The purpose of the process flow diagram is to document the process and provide a foundation for the hazard analysis (step 5). To produce a flow diagram it is necessary to separate the process into a series of steps. In the context of HACCP the word “step” refers not only to obvious processing operations but also to all stages that the product goes through, for example, incoming raw materials, storage. The diagram should progress logically and relate to how the product is actually produced, and should contain enough detail to allow an understanding of the process and for a thorough hazard analysis to be performed. A common error in HACCP is to list the names of the process equipment rather than the process activity and to miss out transfer steps. This often results in an incomplete process flow diagram, which makes the process difficult to follow and if the diagram is incomplete then so too is the hazard analysis. The most commonly used type of flow diagram for use in HACCP studies shows ingredients or groups of ingredients along the top of the page through to the end point with the finished product(s) at the bottom (Rai *et al.* (2015) [63].

5. Confirm accuracy of process flow diagrams

Since the process flow diagram will be used as a tool to structure the hazard analysis, it is important to check and confirm that it is correct. This is done by following through the processing activities in the process area and comparing the documented diagram with what is actually happening, noting any changes necessary, and making sure that all variations, for example, on different shifts, are covered. This exercise is normally done by members of the HACCP team or production personnel. The completed process flow diagram should then be signed off and dated as valid and it is important to make sure that this is done before the hazard analysis commences.

6. Conduct a hazard analysis

Using the process flow diagram(s), the HACCP team considers each process activity in turn and lists any potential hazards that might occur, then performs an analysis to identify the significant hazards and suitable control measures. A number of key HACCP terms are introduced at this stage and these are defined by Codex (2009). The use of Hazard Analysis Charts (Mortimore and Wallace, 2013) [37], which help structure the hazard analysis, allowing HACCP teams to record the important aspects with respect to potential hazard identification, reasoning, and decision-making regarding significance and determination of appropriate control actions. Determination of control measures can include an evaluation of the measures currently in place but it is important to decide whether these are strong enough or if additional control is necessary.

Table 2: Level of Likelihood Occurrence

	Likelihood of Occurrence	Hazard Severity
High	Highly probable; known history in the sector	Life-threatening or long-term chronic illness (eg, infection, intoxication, or anaphylaxis), chronic effects or death
Medium	Could occur; minimal history within the sector but has happened	Injury or intolerance; not usually life-threatening
Low	Unlikely to occur; no known examples	Minor or no effect; short duration

Source: Adapted from Mortimore, S.E., Wallace, C.A., 2013. HACCP—A Practical Approach, third ed. Springer Publications, New York, NY

7. Determine critical control points

Critical control points (CCPs) are the points in the process where the significant hazards must be controlled. The Codex CCP decision tree is a useful tool that is widely used by HACCP teams. hazard analysis, it is very useful to keep a record of the team's discussions and justification of the decisions for future reference and this is normally done using a CCP decision record.

8. Establish critical limits for each CCP

HACCP Principle 3 involves setting critical limits, which are the safety limits that must be achieved for each CCP to ensure that the food will be safe. If the process operates beyond the critical limits then products made will be potentially unsafe. Critical limits are expressed as absolute values (never a range) that define the barrier between "safe" and "potentially unsafe." Critical limits must be measurable and must be established for all CCPs Codex (2009). The difference between critical limits and operational limits is that operational limits are set at "tighter" parameters than required for safety, thus providing a buffer zone for process management by indicating if a CCP is moving out of control, that is, moving toward the critical limit.

9. Establish a monitoring system for each CCP

Once the critical limits (and operational limits, if used) have been established, a monitoring system is needed for ongoing measurement of the CCPs. This needs to be able to demonstrate that the CCPs are working effectively.

Monitoring: The act of conducting a planned sequence of observations or measurements of control parameters to assess a CCP is under control (Codex, 2009). Each monitoring activity should have a person (often called a CCP monitor) who is allocated to perform the monitoring task, record the results and take any necessary actions. In manufacturing, monitoring is usually done by production line personnel who are involved

in operating the processes where the CCPs are located. The ideal situation is to have continuous monitoring systems linked to alarm and action systems.

10. Establish corrective actions

When monitoring shows that there is a deviation from a defined critical limit, corrective action needs to be taken. Corrective action procedures and responsibility need to be identified by the HACCP team during the HACCP study such that they can be implemented by the appropriate operations personnel if deviation occurs. Specific actions are needed that will handle potentially unsafe product and bring the process back under control without delay. The effectiveness of the proposed corrective action plan needs to be verified and challenged since this is the last defense mechanism protecting the consumer from receiving potentially unsafe product should a CCP fail.

11. Establish verification procedures

Verification requires that procedures are developed to confirm that the HACCP system can and is working effectively. There are actually two different types of confirmation required—*validation* and *verification*. These are separate and different activities and both are defined by Codex (2009).

Validation: Obtaining evidence that the elements of the HACCP plan are effective.

Verification: The application of methods, procedures, tests, and other evaluations, in addition to monitoring, to determine compliance with the HACCP plan.

12. Establish Documentation and Record-Keeping

The HACCP plan will form a key part of the documentation, outlining the CCPs and their management procedures (critical limits, monitoring, and corrective action). It demonstrating the validity of the approach and decisions to external auditors.

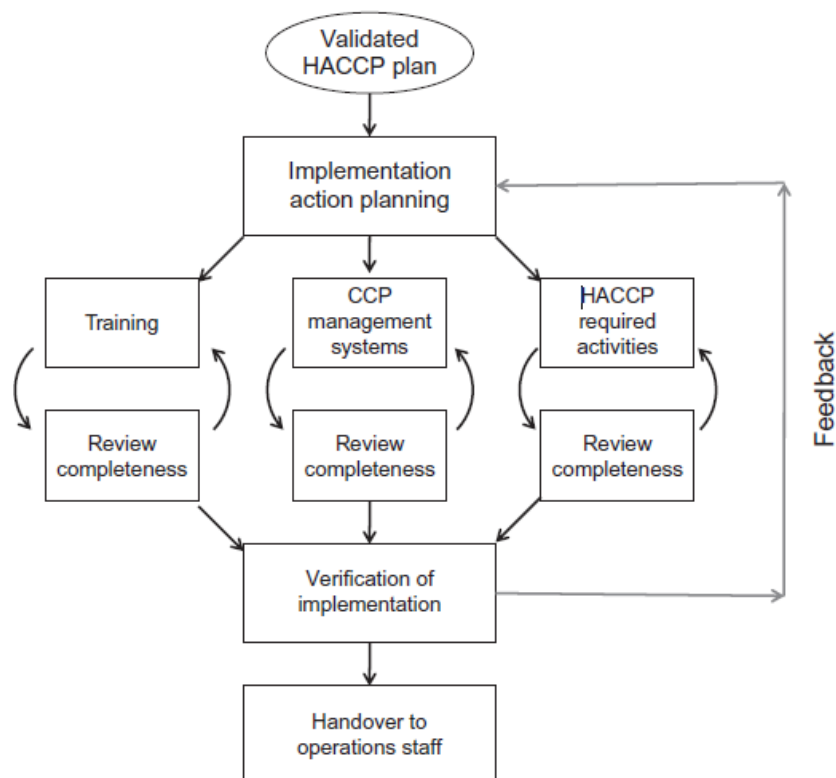


Fig 3: Steps to HACCP implementation. Wallace, C.A., Sperber, W.H., Mortimore, S.E., 2011

Maintenance and archiving of HACCP records is therefore an important element of effective HACCP. Records may be kept as paper archives, however increasingly companies are turning toward computerized record-keeping systems.

Conclusion

Ongoing reinforcement of the hygiene messages in the workplace is essential if desired food handling practices are to be sustained. Improvement in food hygiene practices can also be fostered by provision of a physical and social environment which supports the application of appropriate food handling behaviors. Training activities closely associated with such an environment would be more appropriate than food hygiene courses which operate in settings divorced from the workplace and use solely knowledge-based assessment techniques. Reliable work site evaluation techniques should also be introduced taking account of the fact that knowledge alone does not lead to changes in food handling practices. Good baseline data will be necessary for comparative purposes.

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