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Review

Covid 19 and Food Safety: Guidance for Preventive Techniques in Food Borne Diseases by Micro-organisms

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Abstract. Surface hygiene is commonly measured as a part of the quality system of food processing plants but as the bacteria present are commonly not identified and their roles for food quality and safety are not known. Here, we review the identity of residential bacteria and characteristics relevant for survival and growth in the food industry along with potential implications for food safety and quality. Sampling after cleaning and disinfection increases the likelihood of targeting residential bacteria. The increasing use of sequencing technologies to identify bacteria has improved knowledge about the bacteria present in food premises. Overall, non-pathogenic gram-negative bacteria, especially *Pseudomonas* spp., followed by *Enterobacteriaceae* and *Acinetobacter* spp. dominate on food processing surfaces. *Pseudomonas* spp. persistence is likely due to growth at low temperatures, biofilm formation, tolerance to biocides and low growth requirements. Gram-positive bacteria are most frequently found in dairies and in dry production environments. The residential bacteria may end up in the final products through cross contamination and may affect food quality. Such effects can be negative and lead to spoilage, but the bacteria may also contribute positively, as through spontaneous fermentation. Pathogenic bacteria present in food processing environments may interact with residential bacteria, resulting in both inhibitory and stimulatory effects on pathogens in multi species biofilms. The residential bacterial population or bacteriota, which does not seem to be an important source for the transfer of antibiotic resistance genes to humans but more knowledge is needed to verify this. If residential bacteria occur in high numbers, they may influence processes such as membrane filtration and corrosion.

The use of high temperatures to preserve and ensure the safety of food is based on the effect of microbial destruction. Thermal processing is one of the most widely used unit operations employed in the food industry and is frequency determined as a critical control point. This white paper covers the main science behind the unit operation and should be used to underpin the development and design of thermal processing steps type.

Keywords: food preservation, *Salmonellae* sp., pH value, moisture removal, desorption

Introduction

Micro-organisms are available all over the living place and food stuff has no exclusion (BOARD, 2012). Since micro-organisms are the main cause of food spoilage. Food preservation depends on aversion from conditions favourable for micro-organism growth (Arnold and Martin, 1974) processes for food conservation (i.e. fortification/protection of foods from physical wear and tear due to natural vulnerability or human activity) might generally, organize as drying, heating, refrigeration and the use of chemicals (pesticide, fumigation, cleanliness environment conditions (Datta, 2008). Food preservation is a long lasting desire of humanity (James, 2000). Drying/Dehydrating is the oldest form of food preservation (Shafi-ur-Rehman, 2007). Commencing by primitive living to modern era, humans have used the heat from the sun, fanned by fresh air, to dry everything from mushrooms to fruit and from herbs to seeds for planting the subsequent season (BOARD, 2012), while it has always been an option in hot, dry

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climates, the advents of dehydrators (primitive to electricity) have made drying and dehydrating foods for later utilization (Banwart, 1989). The majority of our foodstuff, stay fit for human consumption just for a short time period, people since the earlier stages, has experimented with methods for successful food preservation (increase shelf life) (Meurillon *et al.*, 2018). The ancient cave man preserved foodstuff whether raw or processed (oil, salts etc.). The key progress and needs in food processing and preservation begin in wars i.e. World War I&II (Arnold and Martin, 1974). During World War II food storage acquires colossal misery for being stored over considerable time period and maintain ingestion qualities as well as nutritional significance and ware houses required be a safe for bacteria (Shafi-ur-Rehman, 2007).

In modern groceries food stuffs are unsafe and hazards for health and associated (Allende *et al*., 2018). Despite of any scientific data, they believed that, synthetic chemicals in our environment and foods, cause varieties of human health problems by oral (Garre *et al*., 2018; Shaw, 2010). Total food preservation would encompass absolute food safety, complete retention of nutritional value and prolonged stability of all food's natural organoleptic properties (fit to eat if good for senses like sight, hearing, feeling, smell and taste) (Shafi-ur-Rehman, 2007). The preservation of food stuffs involves the inhibition of microbial growth and also preservation of colour, texture, flavour and nutrient values (Banwart, 2012).

Food hygiene controlled. Three golden rules of food hygiene controlled food contamination and food poisoning controlled by four 'C's rule i.e. withhold food clean, keep food chilled, cook food, cross contamination avoided reported by (World Health Organization, 2006).

Reasons of food spoilage. Food spoilage occurs, when products developed undesirable odours, flavours and appearances due to micro-organism growth (Alonso *et al*., 2014). In foods, pathogenic (disease producing) micro-organisms are rising or re-emerging due to numerous reasons including globalization of food supply and consumer requirement for fresh tasting, handy to utilize, microbiologically safe foods (Stephen, 2020; CRA, 2000). Various micro-organisms are useful/ beneficial in a way that they can cause pleasing transformation in foods but some microbes cause for food spoilage and harmful for persons by diseases (Shaw, 2010).

Bacteria responsible for food poisoning. Three group of bacteria known that severely cause food poisoning: the *Staphylococci*, the *Clostridia* and the *Salmonellae* (Arnold and Martin, 1974). The *Salmonellae* produce an endo-toxin that survives traditional cooking procedures. Pathogenic micro-organisms (food borne disease causing agents) which can be classified into bacteria, viruses, protozoans, toxins, prions and fungi (Book, 2013).

Vegetative (active micro-organisms) and spore (germ) pathogens (disease producing micro-organism) contaminated any raw food through pollution and gets in pasteurized food, nearby on surface of refrigerator packaging (Notarnicola *et al*., 2017). Dry foods are imputed due to hard foreign objects, spores, aflatoxin etc. (HITM, 2006). Pathogens contaminated food spices from packaging materials leached by toxic agents and any packed food contaminated stored between 41 to 55 °F (5 to 12.8 °C) (James, 2000).

Un-controlled hazardous chemical like (bleaching and cleaning agents), machine oil also catches food, pest control chemicals get hooked onto food and also anything rinsed with water pH≥7.5 may cause food to be contaminated (Book, 2013). These factors conferred consumers to demand towering class foodstuff yield (Banwart, 2012), while cost remains a key standard of most buying choices satisfaction, handiness and health care are driving factors of food market evolution (Smith and Startton, 2006). Thus, researchers and the food industry decided to investigate and to suggest safe products and better quality food having cost effective technologies (Shafi-ur-Rehman, 2007). Ready to cook and ready to eat are most available commercial typed food. Dr. John Harvey Kellogg (MD-USA; 1853-1943) and researching into dietary problems developed "natural food" leading to several well-known products surviving today, including first ready-cooked breakfast cereal, the first flaked cereal food and the cornflake (1899). The Chorleywood baking process (CBP in 1961) is use universal in large scale in bakeries, which increased yield also saved time in wider range of flours (Garre *et al*., 2018).

Food in toxication are consequences from utilization of toxins (or poison) produced in food by bacterial growth (Book, 2013). Toxins may not alter the appearance, odour or flavour of food (Knechtges, 2011). Common kinds of bacteria that produce toxins include *Staphylococcus aureus* and *Clostridium botulinum*

(CRA, 2000). Microbes or spoilage bacteria that deteriorate food are one-celled micro-organisms that can cause fruits and vegetables to get spongy or slick, meat to develop a bad odour (Book, 2013; Shafi-ur-Rehman, 2007). Various factor affected growth and survival of micro-organism in food (Shafi-ur-Rehman, 2007). Growth rate of bacteria in food and other processes is described as exponentially and given by y=(y-intercept)x$e^{b\chi}$; b=growth rate; χ is time and y=population size; for finite resources growth rate occurs for limited time and slows after growth time (Peleg and Corradini, 2011). Similarly, growth decay of population constant rate drops is given by y=(y-intercept)xe^{-bx} (Mackenzie, 2005). Bacterial spoilage can be restrained *via* physical processes like heating to kill them (Knechtges, 2011) and freezing process that slows down their means of propagation (increasing or multiplying) etc. Many bacteria are highly resistant to heat and in some instances, revert to a spore form, by which they can survive high temperature for a long, time period (Balows *et al*., 2012; Banwart, 2012). The preservation of food by radiation has received much attention in food industry research (Li *et al*., 2011). Also, incomplete sterilization can result in instances of botulism (cased is clostridium botulinum, a spore - forming bacterium) or food spoilage (HITM, 2006).

Causes and precautions. Detecting and removing pathogenic micro-organism in foods is important issue (Blaauboer *et al*., 2016). Bacteria and other deleterious micro-organism are more prone to die by heat or thermally kill in a low pH environment (Amin *et al*., 2017). The food sterilization and preservation are role of acidulants (citric acid, tartaric acid etc.) (Aggie Horticulture, 1994). The re-production and growth of bacteria and other micro-organism are inhibited in an acidified medium (defined by pH value) (Shafi-ur-Rehman, 2007). Controlling pathogenic micro-organism in foods is of crucial concern (Shaw, 2010). Their growth and survival in food could be intrinsic and extrinsic (Knechtges, 2011). Intrinsic Factors are water activity a_w, pH and Buffering capacity. Extrinsic Factors are environmental (humidity, air, temperature).

Bacterial food borne infections occur when food, which is contaminated with bacteria and is eaten i.e. orally taken (CDC, 2007) and the bacterium continues to grow in the intestines, setting up an infection which causes illnesses like *Salmonella*, Campylobacter, hemorrhagic *E. coli* and *Listeria* (Altekruse *et al*., 1997).

Salmonellosis (irritable bowel syndrome) is a kind of foodstuff worrying caused by the *Salmonella enterica* bacterium (Ethelberg *et al*., 2014). Young children, older adults and people who have weak immune systems are likely to have ruthless Salmonellosis infections more frequent (Zelman, 2019; Knechtges, 2011). This disease remains an important public health problem in developing countries. In 2000, it was estimated that more than 2.16 million incidents of typhoid fever (*Salmonella enterica* Serotype Typhi) aroused worldwide, resulting in 216,000 casualties and that more than 90% of this morbidity and mortality taken place in Asia (Blum *et al*., 2014). Typhoid fever is a systemic infection caused by *Salmonella enterica* Serotype Typhi (*S. typhi*) (Blum *et al*., 2014). *Salmonella* is a malicious bacterium that occasionally found in the groceries supply, including chicken, tomatoes, peanuts, salsa, guacamole and yet in pet food (FDA, 2018; Knechtges, 2011). It flourishes in the intestinal region of animals and humans and can cause severe gastrointestinal condition due to food contamination (FDA, 2018). Infections vary from meek to very grim illnesses that can kill defenseless population (Blum *et al*., 2014). *Salmonella* is also one of four key global causes of diarrheal diseases (sometimes bloody) and can cause vomiting, abdominal cramps (loathing), nausea, fever, cold and headache, pain (muscle and joint) (Pui *et al*., 2011). Symptoms usually appear 12-72 h after the intake of infected food etc. (HITM, 2006). Warning signs of diseases of salmonellosis includes diarrhea, fever and abdominal cramps that grow in 12 to 72 h after eating, (WHO, 2019). Most people improve in four to seven days (Shaw, 2010) and in severe cases electrolytes require, such as sodium, potassium and chloride ions, lost through vomiting and diarrhea) and rehydration (ORT treatment) (Ratini, 2020).

People with fussy diarrhea may require intravenous fluids (Marler, 2005a). Healthy people may need antibiotic for treating *Salmonella* if infection spread beyond their intestines (Ashton, 2013). Serious and potentially fatal cases can likely to occur in young children, feeble or elderly people and people with weak immune systems (Book, 2013). A small number of people who are infected with salmonellosis develop reactive arthritis, a disease that can last for months or years and can lead to chronic arthritis (Marler, 2015). *Salmonella* may originate by any untreated food of animal sources like meat, poultry, milk and dairy products, eggs, seafood and several fruits and vegetables may transmit *Salmonella* germs (Meurillon *et al*., 2018). People should refrain from eating raw or undercooked meat, poultry or eggs along with un-pasteurized dairy foodstuff (Nielsen, 2017).

Vegetables may also be contaminated (Balows *et al*., 2012). Contaminated foods usually look and smell normal (Wolfram, 2018; FAO/WHO, 2016) whereas, it is good to regularly, soak fruits and vegetables (Dhariwal *et al*., 2017). But it may not get rid of *Salmonella*, mainly due to in an outcrop (exposure to stratum); it's been great to throw away any suspected stuff produced (Kovats *et al*., 1984). Although, foods contains nourishment supplied to all living organisms (humans, animals or plants) (Nielsen, 2017). Additionally, when health warning arose about potentially contaminated food stuff during an outbreak warning, for being avoid eating such stuff, it means that people should not eat that food (either cooked or un cooked) (Wolfram, 2018).

Recommendation to prevent food poisoning from all fruits and vegetables intake may be hand wash with soap and warm water before and after handling them (Zelman, 2019). Wash turn out comprehensively under running water, not in a tub or sink (Shaw, 2010). Use a hygienic cutting floorboard and paraphernalia (knives etc.). Do not allow manufactured stuff/goods to contact with other raw foods or approaches to surfaces they have been placed (Stadler, 2016). Eating contaminated food (with *Salmonella*) may cause salmonellosis, can occur in two ways: (i) The food gets contaminate at some point in food processing or food handling, (ii) The unwashed hands of an infected food handler may pollute the foodstuff (Shaw, 2010).

Non-eating sources of *Salmonella* are like some pets may carry *Salmonella* bacteria in their intestines and their excrement is the apparent concern reported by (Marler, 2005b). A number of particular pets, for example turtles, snakes and other reptiles, chicks and other birds expected to carry *Salmonella* in most cases (Ray and Bhunia, 2007). A person can become infected if he/she does not wash hands after contact with these feces. Reptiles, baby chicks and ducklings and small rodents such as hamsters are particularly likely to carry *Salmonella* (Ray and Bhunia, 2007). Adults should also be careful that children wash their hands after handling reptiles, pet turtles, baby chicks or ducklings, or small rodents. Beef, poultry, milk and eggs are the most infected with *Salmonella* (Balows *et al*., 2012).

Parameters and reasons (methods and working). If food processing included all treatment from place of production to the point of consumption, then 95% or more food is processed (Garre *et al*., 2018). Most of our intake food at least, be trimmed and cooked to make them more palatable and nutritious (Shaw, 2010). Total food preservation would encompass absolute food safety (WHO, 2016), complete confiscation of nutritional value and lengthened stability of all of a food's natural organoleptic properties (fit to eat if good for senses like sight, hearing, feeling, smell and taste) (Shafi-ur-Rehman, 2007). The preservation of food stuffs involves preservation of colour, texture, flavour and nutrient value (BOARD, 2012). Practical control of food deterioration is complicated due to interaction of numerous deteriorative factors like heat, cold, light, oxygen, moisture and time. Further, the highly sensitive organic compounds of food and the biochemical balance of these compounds are subject to destruction by natural environmental variables (Shafi-ur-Rehman, 2007).

Preservation of food availed by controlling growth of micro-organism using physical processes like heat, cold, drying, acid, sugar, salt, smoke, air, chemicals and radiations (BOARD, 2012). Temperature and time are required to destroy micro-organisms, different temperature time combinations are of greatest importance in practical food processing (Kovats *et al*., 1984). The higher the temperature, the shorter will be the time required for microbial destruction (high temperature short time; HTST pasteurization performed in special heat exchangers) (Hadjimbei *et al*., 2015). Grains and dry fruits are dried under the sun (Book, 2013). Dehydrated food products differ greatly in their hygroscopic properties (Imran *et al*., 2017) (materials which bind relatively high amount of water at low activity value are characterized as highly hygroscopic) (Figura and Teixeira, 2007) and in their sensitivity to oxidative deterioration (Ray and Bhunia, 2007). A large number of bacteria can survive food freezing (Book, 2013). The level of moisture required to prevent microbial growth is usually less than 10% (Balows *et al*., 2012), whereas that for preservation of biochemical deterioration is less than 5% but bacteria can proceed to grow rapidly if contaminated frozen food is permitted to thaw and incubate (Bashir, 2022). Also, acid enhances lethality of heat, acid may be found in food naturally or it may be added directly as chemical and it may be produced in a food naturally by fermentation process (Shafi-ur-Rehman, 2007).

Time and temperature controlled safety food (TCS food) is food that requires time temperature control to prevent the growth of micro-organisms and the production of toxins (Knechtges, 2011; NSW, 2008). Potentially hazard food (PHF) may include any animal food, a plant food or a food because of water activity a_w and pH interaction designated to requires product assessment definition (PA) (HITM, 2006). The definition of PHF/TCS from Institute of Food Technologies in 2001 food takes into consideration pH, a_w, pH and a_w interaction, heat treatment and packaging for a relatively simple determination of whether the food requires time/temperature control for safety (NSW, 2008). By measuring the water activity a_w (Fontana and Campbell, 2004) of foodstuffs and it is possible to predict which micro-organism will be potential sources of spoilage and infection (Book, 2013).

A pH, potential of hydrogen measurement reveals if a solution is acidic or alkaline or neutral (Westcott, 2012). Mathematically, pH=-$\log_{10}[H^+]$.$[H^+]$ is positive hydrogen

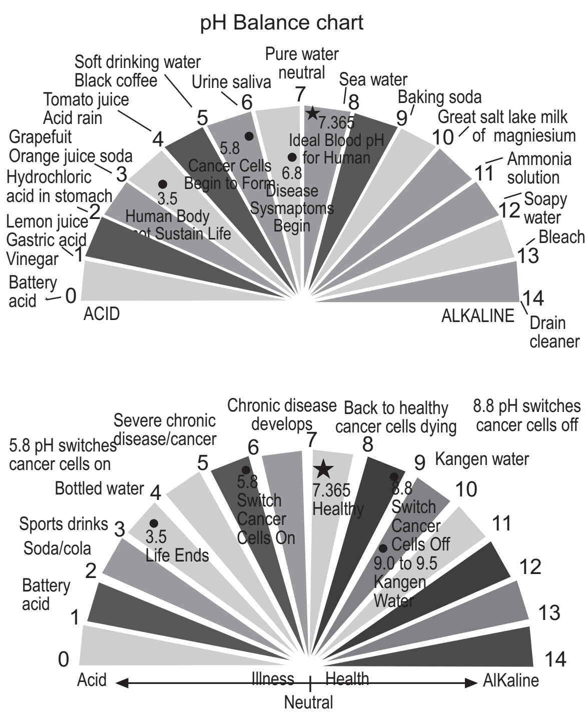

Fig. 1. pH Balance chart (Femalle.net, 2021).

ions concentration, log is log of base 10 (AAC, 2003; Dean, 1999). The negative sign makes pH values positive, as positive hydrogen ions values are small (<1) log is always negative (Dean, 1999).

The most significant function of water is supporting human, animal and plant life (Chen and Rogers, 2018). Since, the most food originates from living substances, water is also a chief constituent in several foods (Banwart, 2012). Water exists in nature as one of three physical states: gas (vapours), liquid and solid (ice) (Dell'Angelo *et al*., 2018). These states are also present in food products to uncertain measure, depending on food's chemical constitution and storage temperature (Park and Bell, 2004). Therefore, chemical, physical and microbial stability of food is affected by properties of water because of the reasons like the high polarity of water making it extraordinarily reactive (Forsythe, 2020; Rao *et al*., 1994).

Water found at various concentrations in our food (Balows *et al*., 2012), roughly speaking, independent of the composition of food materials, higher water concentrations results spoilage caused by growth and development of bacteria and molds due to chemical reactions (Fontana and Campbell, 2004) and on the other hand at low water concentrations food quality losses are caused mainly by autoxidative reactions and physical deterioration (Lajolo and Lanfer-Marquez, 1982). However, the water in side food product articulated in three broad types: free, adsorbed and chemically bonded (Banwart, 2012). Because, free water is more easily removed than bound water, it is the later content in various forms that ultimately affected quality of foods (Chen and Rogers, 2018). The adsorbed water is due to internal and external surfaces of solids like carbohydrates and proteins whose mono or poly-molecular layer adsorbed water (Arnold and Martin,

Table 1. Moisture content of foods (Chen and Rogers, 2018)

Items	% age
Mushrooms	93
Watermelon	92.6
Yoghurt	88-89
Milk	87
Peaches, pineapple	80-87
Potatoes	79
Bananas	75
Eggs	74
Sausage	62
Beef	61-65
Biscuits	28
Honey	20
Peanuts	5.6
Nuts	3.1-3.5

1974). The terms water content and moisture content, which have been used in to the quantity of water present in various food products and ingredients (Aguilera *et al*., 2004). Moisture removal or dehydration, have been used in techniques for food quality controlled since long (Fontana and Campbell, 2004). The relationship between water activity and moisture content (MC) at given temperature is called moisture sorption isotherm (defined for equilibrium of vapour and a_w) (Arnold and Martin, 1974). An increase in water content of food is accompanied by increase in water activity (a_w) (Labuza, 1975).

A plot of water content of a product versus its water activity at a given temperature is called a sorption isotherm (Shafi-ur-Rehman, 2007; Rao *et al*., 1994). The water activity a_w increases with temperature (Fontana and Campbell, 2004). The water activity a_w of a food product describes the degree to which water is bound in side it and its availability to participate in chemical/biochemical reactions and growth of micro-organisms (Arnold and Martin, 1974). Moisture sorption isotherms are sigmoidal in shape for most foods (except for sugar type small soluble molecules, a J-shape isotherm curve shape) (Fontana and Campbell, 2004). Water activity's usefulness in a food quality and safety measurement has no doubt but it is obvious that water content (% or total moisture) could not effectively account for microbial growth their rise and fall (Nielsen, 2017) because the amount of water present often does not adequately characterize to find water capacity or to limit micro-organisms escaping tendency (Book, 2013).

The GAB (Guggenheim-Anderson-de Boer) mathematical model (Shafi-ur-Rehman, 2007) is most widely accepted models for moisture contents (MC) and water activity (a_w) in foods over a wide range of water activity from 0.1 to 0.9 a_w (Fontana and Campbell, 2004). The equation is below:

$$MC = \frac{C_1 k m_o a_w}{(1-ka_w)\,(1-ka_w+C_1ka_w)} \quad \text{...............................(1)}$$

C and k are constants and m_o is monolayer (surface) moisture content. a_w is water activity in material.

In foods, a number of hysteresis effects are observed and are related to moisture adsorption and desorption phenomena in frozen and dehydrated foods (Chou *et al*., 1973). The isotherm for adsorption (from dry state to wet state) and desorption (from wet state to dry) for water activity (a_w) has hysteresis (Rao *et al*., 1994). The water activity (a_w) of pure water is 1.000 (Book, 2013; Leniger and Beverloo, 1975). The measurement range of water activity is 0.030 (nearly dry) to 1.000. The closer a food products value is to 1.000, the more water available in that product to participate in various chemical and physical reactions (Maneffa *et al*., 2017).

Food composition. The total mass of a food is generally the summation of its moisture and solid contents (Chen and Rogers, 2018). Water activity (a_w), not moisture content (MC), determines the lower limit of available water for microbial growth (Maneffa *et al*., 2017). The water activity of any product depends on the chemical composition of product, the state of aggregation of its constituents, the water content and the temperature of product (Ryynanen *et al*., 2004). Water activity (a_w) of a food describes the energy status of water in food (Ali *et al*., 2018). Controlling water activity is important to maintaining the chemical stability of foods due to its ability to act as solvent medium or reactant in chemical or biochemical reactions (Chen and Rogers, 2018). Finally, water activity (a_w), plays an important role in physical properties such texture, taste, colour and shelf life of foods (Hadaweya *et al*., 2017).

Water vapours exhibit vital functions in maintaining aspects and usefulness of food products that we look up in our life (Juliano and Trujillo, 2011). The partial pressure of water vapour (P_o) can vary only if there is a change in absolute temperature (K) or a change in the amount of water vapor (P) (Karalis, 1974). The partial pressure P_o does not vary with a change in total pressure unless the total pressure change is due to a change in the partial pressure of water vapour (P) (Aguilera *et al*., 2004). A localized increase in temperature created by a heater or any apparatus, for instance, does not modify the value of the partial pressure of water vapour (P) (Knechtges, 2011; Rao *et al*., 1994) so, the local vapour pressure is the same throughout the closed space. Water vapour behaves almost like an ideal gas and the following equation applies regarding the partial pressure of vapour:

$P \times V = n \times R \times T$ ....(2) (Arnold and Martin, 1974)

In an open space, the volume (V) occupied by vapour is free to expand. Therefore, the temperature does not affect partial pressure (P) (Jacob, 1999). Hydrogen bonding is stronger in ice. However, when a water molecule leaves a surface and takes gas-form, it has evapourated thus the saturation vapour pressure is locally changed (Leniger and Beverloo, 1975). The potential of water to take part in deterioration processes is characteristic of water activity, given by Raoult's Law: ratio of the water vapour pressure of the product at temperature t_p and saturation pressure of water at the same temperature-t reported by (Lewicki, 2000). Water activity or a_w is a measure of the free moisture in a product and is defined as the ratio of vapour pressure of water (P) in a substance to saturation vapour pressure (vapour pressure of pure water) at a specified temperature (P_o) or at room temperature. ($a_w = P/P_o$&<1 for all substances except water) (Leniger and Beverloo, 1975). Note water activity is not determined by the total quantity of water in a material but only by that which is least tightly bound (having chemical potential energy) (Juliano and Trujillo, 2011; Rao *et al*., 1994).

Knowing and controlling water activity (a_w) in foods can significantly reduce the risk of spoiled or dangerous foods (Brown, 2002). Fresh fruits, vegetables and meats have water activity as 0.970-0.99 allowing the most micro-organism to grow (Banwart, 2012). The lowest a_w at which pathogenic bacteria will grow is about 0.91 with some exceptions like *Staphylococcus aureus* (Brown, 2002). Sugar and salt in foods lower the water activity or free water content of foods (Juliano and Trujillo, 2011). But some micro-organism can survive for a period of time at lower water activity levels waiting for conditions to changed (Book, 2013) whenever a_w increase they actively starts growing as product warms up i.e. its temperature increases, the water activity increases (Medvedova, 2009). Temperature effect on water activity of a food is product specific (Imran *et al*., 2017). Although, temperature change results changes in water binding, dissociation of water etc., due to which water activity is changed (Fontana and Campbell, 2004). In multi component foods moisture migration can occur (Knechtges, 2011). The moisture will migrate from the region of high a_w to the region of lower a_w (Maneffa *et al*., 2017). To controlled water activity within a product, the knowledge of sorption/desorption behavior of food or components, environmental storage conditions and packaging parameters are required (Aguilera *et al*., 2004). Micro-organisms require a minimum pH and a_w in order to grow (Brown, 2002). Furthermore, there are two types of micro-organisms to concern: vegetative (alive) micro-organisms and spore-forming micro-organisms (Arnold and Martin, 1974). Vegetative cells are more easily killed *via* cooking heating up to temp >71.1 °C while only specialized high-pressure, high-temperature devices are able to kill spores (Knechtges, 2011). Micro-organisms generally have optimum and minimum levels of a_w and pH for growth depending on other growth factors in their environment (Arnold and Martin, 1974). Water activity a_w and pH values can be used to predict which micro-organisms will grow in a food (Maneffa *et al*., 2017). Micro-organisms require a minimum pH and a_w in order to grow some spore-forming bacteria, such as Clostridium can subsequently cause food poisoning (Book, 2013). Micro-organisms require water of a specific energy level to grow and survive (Grabowski *et al*., 2006). Additionally, the different species of micro-organisms have pH requirements which must be met for growth to occur (Fontana and Campbell, 2004).

Tables 2 and 3 displayed requirements for water activity (a_w) and pH for forming pathogens. Federal Drug Authority (FDA, 2018).

When no other inhibitory factors are present (Shafi-ur-Rehman, 2007; Rao *et al*., 1994) and the pH and/or water activity (a_w) values are unable to control or eliminate bacterial pathogens which may be present, growth may occur and food borne outbreaks result (Alonso *et al*., 2014). Intrinsic factors are unable to control bacterial growth once pathogens exposed to the cellular fluids and nutrients after cutting. It is probable that neither the pH value nor a_w value is low enough by itself to control or eliminate pathogen growth; however, the interaction of pH and water activity (a_w) may be able to accomplish it.

Table 2. Interaction of pH and a_w (NSW, 2008)

	pH Values			
a_w Values	<4.2	4.2-4.6	>4.6-5.0	>5.0
<0.88	Non-PHF*/Non-TCS food**	Non-PHF/Non-TCS food	Non-PHF/Non-TCS food	Non-PHF/Non- TCS food
0.88-0.90	Non-PHF/Non-TCS food	Non-PHF/Non-TCS food	Non-PHF/Non-TCS food	PA***
>0.90-0.92	Non-PHF/Non-TCS food	Non-PHF/Non-TCS food	PA	PA
>0.92	Non-PHF/Non-TCS food	PA	PA	PA

*PHF=Potentially hazardous food; **TCS food=Time/temperature control for safety food; ***PA=Product assessment required.

Table 3. Interaction of pH and a_w. (NSW, 2008)

	pH Values		
a_w Values	<4.6	>4.6-5.6	<5.6
<0.92	Non-PHF*/non-TCS food**	Non-PHF/non-TCS food	Non-PHF/non-TCS food
>0.92-0.95	Non-PHF/non-TCS food	Non-PHF/non-TCS food	PA***
0.95	Non-PHF/non-TCS food	PA	PA

*PHF=Potentially hazardous food; **TCS food=Time/temperature control for safety food; ***PA=Product assessment required

Rectification methods. Low temperature(refrigerating and freezing) is a key requirement to preserve food, industrial samples, vaccines and drugs, as it does not degrade products and keep materials from being spoiling (Aste *et al*., 2017). Often, materials sensitive to low temperature shipped beyond the temperature confines regions, therefore, maintaining the cold chain is a considerable challenging (Hadaweya *et al*., 2017), dry ice is a common means of preservation, as it is readily available and relatively cheap (Banwart, 2012). However, using containers filled with dry ice presents a temperature maintenance challenge (Notarnicola *et al*., 2017). In a multiple component food product, controlling the rate at which individual food components absorb energy and heat up is critical to achieving overall thermal uniformity (Aguilera *et al*., 2004). Individual component shape, evenness of main component size and liquid content viscosity are all important factors in this respect (Chen and Rogers, 2018). Many environmental/chemical reactions yield water as a product i.e. at temperatures higher than the dew point of the surrounding air, the water vapor will be formed and result in increasing the amount of water vapour in the volume/gas (Dean, 1999; Karalis, 1974). Contrarily, reaction takes place at temperatures lower than the dew point, condensation will occur and water vapor will leave the gas making it dry (Karalis, 1974). Other chemical reactions take place in the presence of water vapour, resulting in new chemicals forming, such as rust on iron or metal (Blaauboer *et al*., 2016). Food contains moisture and protein and thus become neutral or slightly acidic (pH≤7) (Sundberg *et al*., 2013). Most bacteria need nutrients such as carbohydrates or proteins to survive during storage at 41 to 135 °F (Meggitt, 2003). Although the low water activity environment is not suitable to grow microorganisms, low water activity foods are liable to be contaminated by microorganisms during harvesting, processing or transportation (CDC, 2007).

Low moisture foods including dried spices, vegetable powders, whole milk powder and corn and wheat flour, are defined as food with water activity (a_w) less than 0.7 or moisture content (MC) below 20% (Pui *et al*., 2011). The pasteurization of Salmonella contaminated low moisture foods is difficult because of the high heat

Table 4. Minimum growth condition for micro-organism

Micro-organism	Minimum ph for growth	Minimum a_w for growth	Minimum growth temperature (°C)	Anaerobic growth
Bacteria				
Pseudomonas	5.5	0.97	<0	No
most spoilage	variable	0.90	variable	variable
pathogens	>4.6	>0.85	variable	Yes
Lactic acid bacteria	3.8	0.94	4	Yes
Yeast				
Refrigeration	<2.0	0.80	-5	Yes
most spoilage		0.88		
osmophilic		0.61		
Mould				
Refrigeration	<2.0	0.60	<0	No
most spoilage		0.80		
xerophilic		0.61		

Minimum growth condition for interaction of pH and water activity (a_w) (Curale and Vestergaard, 2001).

resistance of *Salmonella* (virus) in low water activity environment (Mañas *et al*., 2003).

FATTOM is a short form used to explain conditions of bacterial growth (F=food; A=acidic; T=temperature; T=time; O=oxygen; M=moisture). International Dairy Deli Bakery Association (IDDBA, 2013).

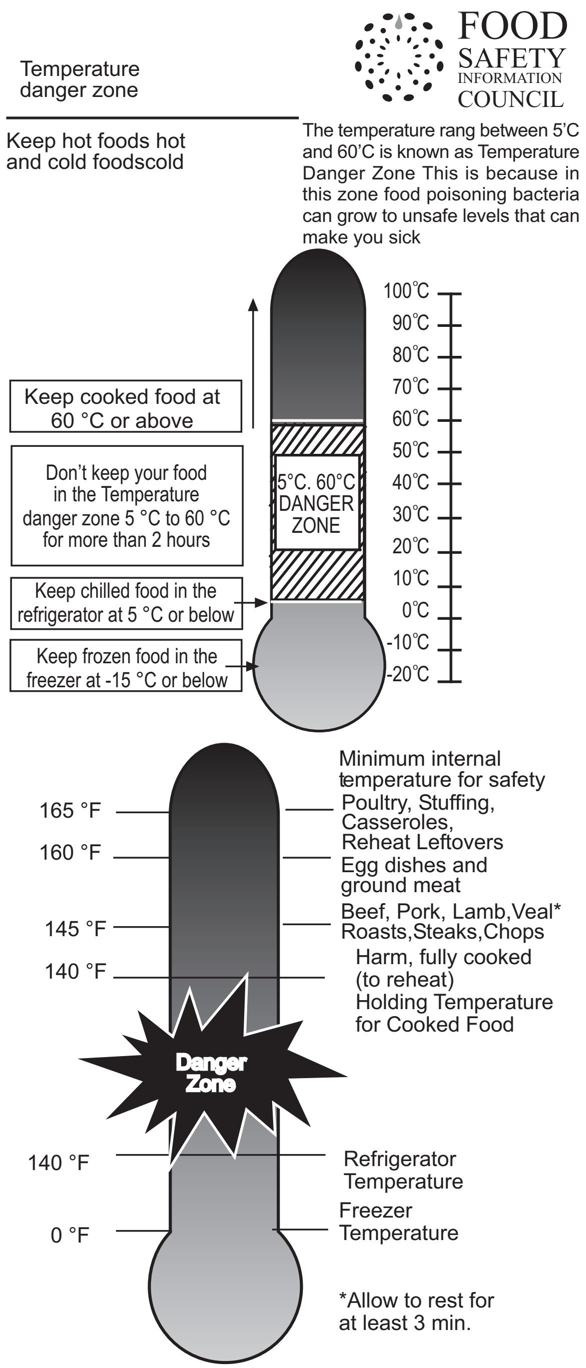

Fig. 2. Food safety and inspection service (FSIS), 2017.

Salmonella bacteria grow at temperatures between 41 to 113 °F (5 to 45 °C) (Knechtges, 2011; Pui *et al*., 2011). Although, they are destroyed by cooking to 160 °F (71.11 °C) and do not grow at refrigerator or freezer temperatures (below 5 °C) (Mackey and Derrick, 1987a). But they do endure refrigeration and freezing will initiate growth again once warmed to surroundings temperature (Meggitt, 2003). Some bacteria can route/get methods to a spore form after surviving unfavourable conditions (non-culture ability state) (Talukdar *et al*., 2017). This mechanism is like Hibernation (habit of various animals hibernates which go into a yawning sleep, so they can endure the cold season when the weather is freezing and the food is limited). Hibernation is a clever survival mechanism, they still breathing even though not really doing anything (Knechtges, 2011). In the same way, bacterial spores are extremely resistant; surviving extreme dryness, subzero temperatures, as well as high temperatures (sporulation) (Talukdar *et al*., 2017; Shafi-ur-Rehman, 2007). Once conditions (temperature, pH, a_w) become favourable for re-growth, the spores will come back to life and begin multiplying (vegetative) (Talukdar *et al*., 2017; Knechtges, 2011).

Some foods did not support growth to micro-organism (non-PHF) but may contain a pathogenic micro-organism of chemical/physical food safety hazard that cause food borne illness or injury (Knechtges, 2011). Although, cooking could easily killed vegetative cells (Meggitt, 2003), while only specialized high pressure, high temperature devices are able to kill spores, viruses cannot multiply in foods (Talukdar *et al*., 2017), although a single viral particle has the theoretical potential to produce a per-oral infection (Book, 2013).

Practical workout. ***Decontamination methods.*** Different decontamination methods have been applied to reduce the microbial hazard of low moisture foods, such as steam, hot air and irradiation. The most widely used means if inactivating foodborne viruses is heat (Knechtges, 2011). However, conventional heating methods including steam and hot air require long processing time (Amin *et al*., 2017), which leads to severe quality degradation in low moisture foods, due to their low thermal conductivity (Rao *et al*., 1994). Dehydration is a mechanical methods and is process of reversibly removing water from food so that the storage life is extended by the prevention of microbial growth (Amin *et al*., 2017), the main factor that affects rate of drying and time of drying cycle: (a) physical properties of the product; (b) geometrical arrangement of product in relation to heat transfer

Table 5. Micro-organism and viruses (commonly found) vs. disease type (Book, 2013)

Micro-organism and viruses (commonly found)	Disease type
Pathogenic bacteria (Gram-negative bacteria)	
Salmonella spp.	*Salmonella* can cause two types of illness depending on the serotype: (1) Gastrointestinal illness or nontyphoidal salmonellosis and (2) typhoid fever.
Campylobacter jejuni	The disease caused by *C. jejuni* infections is called campylobacteriosis and is self-limiting gastroenteritis, termed "Campylobacter enteritis,"
Yersinia enterocolitica (*Yersinia enterocolitica* and *Yersinia pseudotuberculosis*)	*Y. enterocolitica* and *Y. pseudotuberculosis* cause gastroenteritis, and include reactive arthritis; glomerulonephritis; endocarditis; erythema nodosum
Shigella spp. (*Shigellasonnei*, *S. boydii*, *S. flexneri* and *S. dysenteriae*)	The illness caused by *Shigella* is shigellosis (also called bacillary dysentery), in which diarrhea may range from watery stool to severe, life-threatening dysentery.
Vibrio parahaemolyticus	It can cause bloody diarrhea, stomach cramps, fever, nausea and vomiting, which usually are fairly mild
Coxiellaburnetii	This bacterium causes a disease called Q fever, which can exist in two different forms. (1) In one form, symptoms usually go away on their own or with antibiotics. (2) The other, chronic form is more serious and can lead to death of untreated cases.
Brucella spp.	Brucellosis, disease caused by *Brucella*, also is called "undulant fever," because the high fevers and sweating that are characteristic of the illness come and go.
Vibrio cholerae Serogroups O1 and O139	Vibrio cholerae serogroups O1 and O139 are responsible for epidemics and pandemic cholera outbreaks and causes watery diarrhea. Vomiting also may occur.
Vibrio cholerae Serogroups non-O1 and non-O139	Non-Ol non-O139 V. cholerae causes gastroenteritis. Occasionally, it causes septicemic infections include chronic liver disease (cirrhosis, hepatitis, liver transplantation, and cancer of the liver), elevated serum iron levels (hemachromatosis), compromised immune system, other chronic illnesses (diabetes, renal disease, intestinal disease)
Vibrio vulnificus	Gastroenteritis caused by *V. vulnificus* is characterized by fever, diarrhea, abdominal cramps, nausea, and vomiting.
Cronobacter species (*Enterobacter sakazakii*) spp.	Cronobacter can cause bloodstream and central nervous system infections. This bacterium is especially risky for newborn infants.
Aeromonas species, *Aeromonas hydrophila*, *Aeromonas caviae*, *Aeromonas sobria*, *Aeromonas veronii*.	In people with impaired immune systems, *A. hydrophila* may spread throughout the body and cause systemic infections.
Plesiomonas shigelloides	This pathogen has been associated with human diarrheal diseases. shigelloides gastroenteritis usually is a mild, self-limiting infection, although a more severe, dysenteric form of gastroenteritis may occur.
Miscellaneous bacterial enteric (*Klebsiella*, *Enterobacter*, *Proteus*, *Citrobacter*, *Aerobacter*, *Providencia*, *Serratia*)	These bacteria causes acute or chronic gastroenteritis – watery diarrhea and other symptoms that may include nausea, vomiting, cramps, pain, fever and chills.
Francisella tularensis	The bacterium *Francisellatularensis* causes a disease called tularemia (nicknamed "rabbit fever", deerfly fever, hare fever, and lemming fever).

Continued

Pathogenic *Escherichia coli* group	
Enterotoxigenic Escherichia coli (ETEC)	ETEC causes gastroenteritis in humans and is best known as the causative agent of travelers' diarrhea. It is also an important cause of diarrhea in infants. Illness from ETEC is usually self-limiting, mild and brief.
Enteropathogenic Escherichia coli (EPEC)	The disease usually associated with EPEC is infantile diarrhea and it is highly infective in infants.
Enterohemorrhagic Escherichia coli (EHEC) (EHEC O157:H7)	Infections from EHEC may range from asymptomatic-to-mild diarrhea to severe complications, the infection sometimes progresses into the life-threatening form of the illness that causes kidney failure and other problems.
Enteroinvasive escherichia coli (EIEC)	The illness caused by EIEC is a mild form of bacillary dysentery, similar to that caused by *Shigella* spp.
Pathogenic bacteria gram-positive bacteria	
Clostridium perfringens	It makes a toxin in the intestines. The toxin causes two major kinds of foodborne illness. Symptoms include pain and gassy bloating in the abdomen, diarrhea (maybe bloody) and vomiting.
Staphylococcus aureus	Often called "Staph" for short toxins can cause nausea, stomach cramps, vomiting, and diarrhea.
Bacillus cereus and other *Bacillus* spp.	Often called "*B. cereus*" this bacterium can cause two different types of sickness. The diarrheal type of illness and The vomiting (emetic) type.
Streptococcus spp.	*Streptococcus bacterium* causes "Strep throat" or pharyngitis. The infection may also result in complications, such as tonsillitis, scarlet fever, rheumatic fever and septicemic infections.
Listeria monocytogenes	*L. monocytogenes* is among the leading causes of death from foodborne illness The foodborne *Listeria* is comparatively small.
Mycobacterium bovis	*Mycobacterium bovis*, also referred to as *Mycobacterium tuberculosis*. *Mycobacterium bovis* causes tuberculosis in cattle and is considered a zoonotic disease
Clostridium botulinum	*C. botulinum* infection results in flaccid paralysis of muscles, including those of the respiratory tract.
Enterococcus	*Enterococci*, in general, can cause many different infections, such as endocarditis, bacteremia, urinary tract infections, intra-abdominal and pelvic infections and nosocomial infections and neonatal infections.
Viruses	
Noroviruses	Norovirus illness or NoV infection is self limiting, but can be very debilitating as a result of the high rate of vomiting. Dehydration is the most common complication, especially among the very young.
Hepatitis A virus	Hepatitis A virus (HAV) infection include fever, anorexia, nausea, vomiting, diarrhea, myalgia, hepatitis and often, jaundice.
Hepatitis E virus	Hepatitis E Virus (HEV) is a known cause of epidemic and intermittent (sporadic) cases of enterically-transmitted acute hepatitis.
Rotavirus	Human rota viruses (HRV), it's especially a problem for infants and children. It's one of the main causes of diarrhea and dehydration (losing too much body fluid) in this age group..
Prions and transmissible spongiform encephalopathies	Prions (pronounced "PREE – ons") and Transmissible spongiform *Encephalopathies* (TSEs) are neurodegenerative diseases. Variant Creutzfeldt-Jakob (vCJD)

surface or medium; (c) physical properties of drying environment; (d) characteristic of drying equipment (Wang *et al*., 2008).

Molecular biologist has studied the heat shock response of bacteria and germs (Ray and Bhunia, 2007). Heat shock response is a cell's response to intense heat (also called global/universal response), heat shock is a swift rise in the environmental temperature that results in different physical and chemical changes in bacteria (Rosen and Ron, 2002). An experiment (conducted by Mackey and Derrick, 1986) with *Salmonellae* spp. demonstrate that when heat shock is induced in bacterium (*Salmonella thompson*) by pre incubation the cells at 48 °C for 30 min. the thermal death determination can take place (Mackey and Derrick, 1986). In this work it is also observed, that rate of temperature increase the degree of thermal resistance (i.e. level of heat shock induced) (Mackey and Derrick, 1987a). In real, bacterial stress-responses, enables bacteria to survive from unfavourable and un-predictable conditions in their living environment and bacterial cell can react simultaneously to a wide variety of stresses (Knechtges, 2011). A slow rise in temperature (as 0.6 °C/min) induced far more thermal resistance (to survive) in bacterial cell than a more rapid rise (e.g. 10 °C/min) (Peleg and Corradini, 2011). An instantaneous shift to the final lethal temperature gave thermal death rate very high and similar to non-heat-shocked (control) strains cell death rate (Mackey and Derrick, 1987b). Therefore, rise in temperature as quickly as possible may be needed to kill pathogens in food (Knechtges, 2011).

Water exists in food as free moisture capable of exerting vapor pressure and causes a number of hysteresis effects related to moisture adsorption and desorption phenomena (Chou *et al*., 1973). Since, food science is concerned with the knowledge of physical, chemical and biological including nutritional, properties of food (Shaw, 2010) and their constituents and changes they undergo when subjected to handling, preservation, processing, storage and distribution (WHO, 2016), Actually, the state of water in foods has strong influence in de-contamination process of natural foods like vegetable and meats (the food composed of cellular materials-proteins) (Rao *et al*., 1994). Accordingly, freezing of water, is an exothermic reaction (Ray and Bhunia, 2007) and melting of ice is example of endothermic reaction. When ice melts, energy is absorbed from environment to convert ice crystal into water and boiling of water involves absorption of energy which break hydrogen bonds and keeps holding water into liquid state, water evapourate by means of change to gaseous phase (Aguilera *et al*., 2004).

Conventional hot air (HA). HA drying is widely used method for dehydrating food stuff (SkočIlas *et al.*, 2016). The zeroth law of thermodynamics states that heat flows from higher to lower temperatures (Rao, 2004). The first law is the conservation of energy between work and heat (Samuelson, 1992). When any material is heated or cooled the physical and chemical states are commonly changes, due to which change in energy level results (Boye, 2004; Rao *et al*., 1994). These conversion can be endothermic or exothermic (Lumen, 2017a).

In treatment of food, conventional hot air oven use a combination of mechanisms, depending upon type, convection from the heat source, whether from gas burner or electric heater, then conduction from the air into the food (Rao *et al*., 1994). The hot air (HA) flow drying of food gets major drawbacks in processing of food such as long drying time and colour degradation of a dried product since thermal runaway, which is directly proportional to temperature and heating time (Kocabiyik and Tezer, 2009). Thus, researchers convinced to search for new technologies in need to remove these problems and employ microwave dryers (MD) to optimize the heat transfer process and used efficient system (Kassem *et al*., 2011).

Induction heating (IH). Induction heating (IH) is heating technology possess high safety and efficiency and similar to the microwave heating i.e. electromagnetic radiation exciting molecules in the pot and then conduction into the food (El-Mashad and Pan, 2017). An induction heater consists of three basic elements: current supply source, heating inductor and charge feeding system. A typical diagram of an induction heater has been presented in Fig. 3 (Smalcerz and Przylucki, 2013). Induction heating can utilized as low power equipment (upto 50 kW), medium power (upto 200 kW) and high power (above 200 kW) with frequency ranges from power line frequency (50-60 hz) to extremely high frequency (300 kHz to 27.12 MHz) (Habash, 2001) but processing with induction heating, may given out unreliable measurement temperature readings and often deviations can range from several to tens of percent (Smalcerz and Przylucki, 2013). Research is also needed to compare the efficiency of the induction heating and other heating technologies, such as infrared, microwave and ohmic heating, for food processing applications (El-Mashad and Pan, 2017).

Ohmic heating. It can be used in several sectors of food processing such as thawing process, blanching, sterilization, pasteurization, enzyme inactivation, expression, extraction, desalination and waste water treatment, rice bran stabilization, tofu making process, semi meat ball cooking and drying process etc. (Pereira *et al*., 2007). Ohmic heating is a resistance heating technique for liquids and pumpable particles (Patel and Singh, 2018). Ohmic heating Fig. 4 is an electrical resistance heating method for the heat treatment of food products (Allali *et al*., 2010). When electric current passes through the food, due to its internal electrical resistance or conductivity (Tulsiyan *et al*., 2008).

In this process heating rate depends upon the electrical conductivity (of process food) and applied field strength but both tends towards wide-ranging in multi component food (Zareifard *et al*., 2014).

By this method a product undergoes a minimum structural damage retain its nutritional value (Patel and Singh, 2018). However, these above methods suffer several dilemmas such as reduced outcome with quality and low operation performance (efficiency) (Laguerre Jean-Claude and Agha, 2020). Generally, in conventional drying method, two steps take place: a heat transfer from hot and dry surrounding medium to the product and then a mass (water and/or volatile compounds) transfer from the product to the surrounding atmosphere (Hadaweya *et al*., 2017).

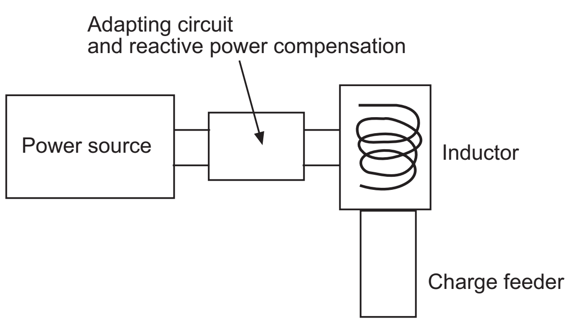

Fig. 3. Induction heater.

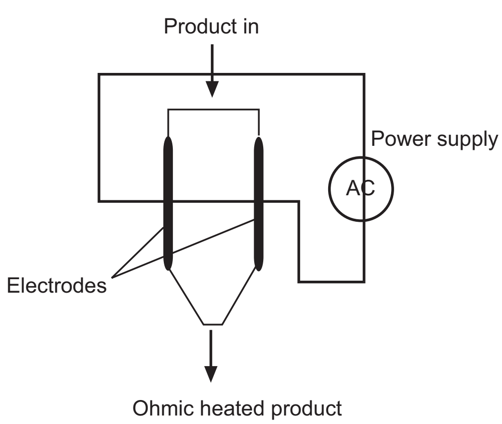

Fig. 4. Ohmic heating.

Irradiation. Electromagnetic (EM) wave transmission and interaction with materials plays an important role for food decontamination (Garre *et al*., 2018). The role of electromagnetic waves are further researched in recent years and it's associated with wave absorption, transmission and scattering properties (Tang *et al*., 2010). The thermal heat transfer by radiation occurs from higher temperature body towards lower temperature and by electromagnetic waves (Grandison, 2012). Thermal radiations falling on a matter increases its temperature (Křivánek, 2008) and it may be absorbed (define by absorptive -α), reflected (defined by reflectivity -ρ) or transmitted (defined by transmissivity -τ); depending upon material of body (Smith, 2004; Habash, 2001). These fraction add up to unity i.e. $\alpha+\rho+\tau=1$ (Smith, 2004).

The World Health Organization (WHO) is fearful with regards to the increase of food borne diseases and is in favour of irradiation treatment of food (Rocourt *et al*., 2003). A joint FAO, IAEA and WHO expert committee meeting in (Geneva, 1981) concluded that the irradiation of any food commodity upto an overall average dose of 10 Kg presents no toxicological hazard (Raffi, 2004). Later, 10 Kg limit were also tolerated (Loaharanu and Thomas, 2001). The radiation dose Kjoule absorbed by the food which is the most critical factor in food irradiation (WHO, 1988). The special name for the unit of absorbed dose is the gray (Gy). It is defined as the mean energy imparted by ionizing radiation to matter per unit mass (WHO, 1988). One Gy is equal to one joule/Kg: one Gy=1 J/Kg: older unit is rad=0.01 Gy (Raffi, 2004). The physical, chemical and biological effects are linked to irradiation dose, which is quantity of energy absorbed by matter (upto 50 KGy used for sterilization i.e. to reduce micro-organisms). If the amount of radiation delivered is less than the suitable dose, the proposed outcome may not be achieved (Amin *et al*., 2017). Conversely, if the dose is in excess, the food product may spoil and become un-acceptable (WHO, 1988). But irradiated food cannot be, recognized by sight, smell, or taste, the only way of knowing it, is the food processed has label to announce the treatment (Raffi, 2004). Growing knowledge of irradiation preservation will reduce microbiological spoilage and wastage of foods and indirectly it reduces the risk of food poisoning from mishandling in home and in catering (Garre *et al*., 2018).

An electromagnetic radiation (waves) propagates with speed of light $c=2.998x10^8$ m/s having characteristic wave length (λ) or frequency (ϑ);

$c=\vartheta x\lambda$..(4) (Smith, 2004),

but emission radiation has discrete energy as given by

$E=hx\vartheta$..(5)

(jouls or eV); (h=planks constant=6.6256 $x10^{-34}$ Jouls) reported by (Habash, 2001).

The relationship between amount of radiation absorbed, the wavelength of wave and concentration of absorbing species (biological molecules) is given by

Lambart-Beer's law: $A=\varepsilon bc$ ....(6)

where:

b=path length (thickness in food); c=concentration (in material/solution); ε=specific for molecules being investigated (centricity coefficient) (Bower *et al*., 2003).

Electromagnetic waves (EM) require no material means for their propagation/transmission (Online Science Help, 2013). The sun spreads nearly all of its energy throughout the vacuum and space towards all planets including our earth by means of radiation (EM waves). Light is just one segment in a range of electromagnetic spectrum travels through space. These waves have wave length and frequency values, which distinguish light from other forms of energy on the electromagnetic spectrum (Sankaran and Ehsani, 2014). The light waves are capable of exciting the eye's retina, which results in a visual sensation called sight (Udayakumar, 2014). Light and radio waves can travel through interplanetary and interstellar space from the sun and stars to the earth. Regardless of their frequency and wavelength, electromagnetic waves travel at a speed of 299,792 Km/h (186,282 m/h) in a vacuum (Franklin *et al*., 2010).

These EM waves are also called "Electromagnetic radiation" because they are radiated from the electrically charged particles (Vidal-Bortóns *et al*., 2003). The motion of electrically charged particles produces electromagnetic waves. Radio waves, microwaves, visible light and X rays are all have different frequencies and are represented from a number ranged 0 Hertz to 300 GHz (as above Table 6, electromagnetic spectrum) (Habash, 2001). Like other natural sources radio and microwaves (ionization waves) can also produce by artificial methods (Franklin *et al*., 2010). Microwave and infrared radiation are forms of electromagnetic radiation, transmitted in matter/food as waves and both are converted to heat energy (Datta, 2003).

Microwaves are very high frequency signals (3,000 MHz to 30 GHz) (Smith, 2004) and this high frequency permits large amounts of energy to be transmitted through food/matter (Datta, 2003; Kolbe, 2003). Radio waves are traveled in Omni direction whereas microwave traveling is focused and unidirectional by waves guideb (Ştefănoiu *et al*., 2016). That means that microwave travel in straight line (line-of-sight transmission) (Habash, 2001). Microwaves (300 MHz and 300 GHz) and radio waves (3 KHz and 300 MHz) are a types of radiation which stimulate the water molecules in food and excite them (vibrate water molecules in side and on surface) so the heat transferred internally by conduction (the reason is their wavelength as compared with diameter of water molecules H_2O which starts oscillating with field). There are two mechanisms involved: dielectric heating and ionic migration under field (Ştefănoiu *et al*., 2016).

The radio frequency (RF) covers a wide band of frequencies ranging from 3 kHz to 300 MHz (Datta, 2003) but only three frequencies i.e. 13.56 MHz ± 7 kHz; 27.12 MHz ± 160 kHz and 40.68 MHz ± 20 kHz are used for industrial, scientific and medical appli-

Table 6. Electromagnetic spectrum (Sankaran and Ehsani, 2014).

		Wavelength (m)	Frequency (Hz)cycles/sec	Energy(J)
Radio waves		$>1 x10^{-1}$	$< 3 x 10^{9}$	$< 2 x 10^{-24}$
Micro waves		$1 x10^{-3} - 1 x10^{-1}$	$3 x 10^{9} - 3 x 10^{11}$	$2 x 10^{-24} - 2 x 10^{-22}$
Thermal radiation		$1 x 10^{-7} - 1 x 10^{-4}$	$3 x 10^{9} - 3 x 10^{11}$	$2 x 10^{-24} - 2 x 10^{-22}$
Infrared		$7 x10^{-7} - 1 x10^{-3}$	$3 x 10^{11} - 4 x 10^{14}$	$2 x 10^{-22} - 3 x 10^{-19}$
Optical/visible		$4 x 10^{-7} - 7 x10^{-7}$	$4 x 10^{14} - 7.5 x 10^{14}$	$3 x 10^{-19} - 5 x 10^{-19}$
UV	Ionizing Waves	$1 x10^{-9} - 4 x10^{-7}$	$7.5 x 10^{14} - 3 x 10^{16}$	$5 x 10^{-19} - 2 x 10^{-17}$
X-rays		$1 x10^{-11} - 1 x10^{-9}$	$3 x 10^{16} - 3 x 10^{19}$	$2 x 10^{-17} - 2 x 10^{-14}$
Gamma-rays		$<1 x10^{-11}$	$>3 x 10^{19}$	$> 2 x 10^{-14}$

(Wavelengths, frequency and energies of electromagnetic spectrum region) cations, (International Labour Organization (ILO), 1998). Radio waves have wavelengths (distance between two consecutive crusts) upto 1 m and have frequency 300 MHz ($300 x 10^6$) (Smith, 2004).

Infrared radiations (IR) are electromagnetic radiation emitted by hot objects (Ştefănoiu *et al*., 2016). All matter with temperature greater than absolute zero emits thermal radiation. When the temperature of the body is greater than absolute zero, inter-atomic collision causes the kinetic energy of the atoms or molecules to change. This results in charge acceleration and dipole oscillation which produces electromagnetic radiation (Wikipedia, 2021a). The heat transfer depends on surface temperature of both bodies (emitter and absorber), surface properties of materials, shape of emitting and receiving bodies and a perfect radiator (black body; emissive power of a black body is proportional to fourth power of absolute temperature). In fact, energy transfer by radiation is the fastest (at the speed of light) and it suffers no attenuation in a vacuum. This is exactly how the energy of the sun reaches the earth (Smith, 2004).

Infra-red (IR) heating. IR heating or RF system uses parallel plate electrodes (Datta, 2003). One of these electrodes is grounded which sets up a capacitor to store electric energy. The targeted material to be heated is placed between the two electrodes without touching the parallel electrodes (Ştefănoiu *et al*., 2016). It must be noted that the use of parallel plate electrodes (or through field applicators) is most commonly used electrode configuration for heating thicker materials. These are fringe-field applicators which consist of a series of bar, rod or narrow plate electrodes which are most suited for heating or drying thin layers (<10 mm) or staggered through field applicators are used for intermediate thickness materials heating. Infrared radiations has disadvantages like less controlled and wider range of frequency, lean penetration, heating depends on surface characteristics of food and colour of food (Datta, 2003). Equipment required for IR generation is radiant heater like metal, ceramic, quartz, halogen and main purpose is drying low moisture foods (Ştefănoiu *et al*., 2016; Marra *et al*., 2010; Marra *et al*., 2009).

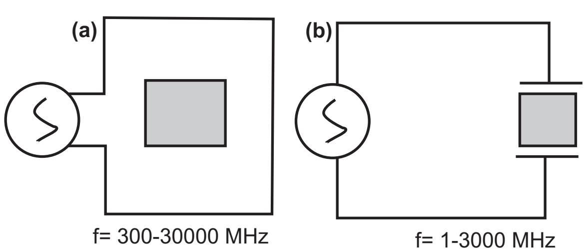

Fig. 5. Microwave and radio frequency arrangement.

Microwave electromagnetic waves ranges from 30 cm to 1 mm in wavelength (frequency range from 3 GHz to 300 GHz) and micro wave food processing uses two frequencies, 915 MHz and 2.45 GHz for food products heating (Datta, 2003). Its uses/applications are dehydration and baking, thawing and defrosting.

For a microwave ovens using electromagnetic waves at a frequency of 2.45 GHz (wavelength about 12 cm) that make water molecules vibrate fast and heat up (Datta, 2003). Microwaves can travel through glass and plastic and penetrate about a centimeter into food (depending on the food), but bounce off metal surfaces. There must always be something to absorb the microwaves, such as food or a glass of water (Zhang and Datta, 2001).

The apparatus has: magnetron, resonance cavity (metallic case), wave guides, stirrer turn Table.

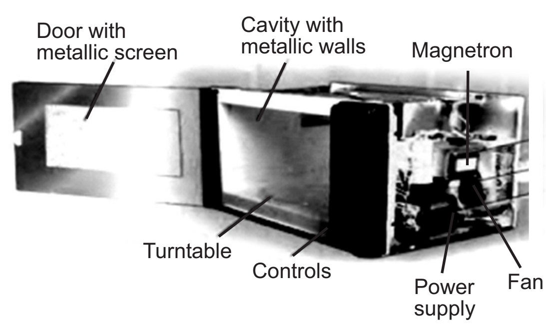

Fig. 6. Home microwave oven.

Microwaves are created by the magnetron, are sent in different directions by the stirrer, bounce off metal surfaces and are absorbed by the water molecules in food (Ştefănoiu *et al*., 2016). In a magnetron a central electron emitting cathode of highly negative voltage is surrounded by an anode that includes cavities (Gabriel *et al*., 1998). The cavities have the right dimensions to be resonant with the intended microwave frequency (Dibben, 2001). The emitted and accelerated electrons are deflected by magnetic field to spiral motions. By passing the cavities, energy transferred to the developing standing wave within the cavities, being coupled by antenna into the waveguide (Zhang and Datta, 2001). Magnetron of different output power exists (Kudra and Mujumdar, 2002). Devices that are used for guiding the microwaves to the applicator (where the microwave treatment takes place) are coaxial line and waveguides (Dibben, 2001). The latter are just hollow conductors of rectangular or circular cross-section. Due to smaller losses, waveguides are proposed for used in high power applications.

Furthermore, circulators directionally dependent microwave travelling devices are used that let the incident wave pass and guide the reflected wave into an additional load and tuners are often used to match the load in order to minimize reflected power (Zhang and Datta, 2001). The temperature transmission within food heated with microwave is determined by thermal properties of food and the distribution of absorbed microwave energy. The energy absorbed, is govern by electromagnetic field (Dibben, 2001). Microwave heating is due to electromagnetic radiation creating molecular friction in water molecules $_{+H}\,^{O-}{}_{+H}$ then it forms an electric dipole (Ştefa˘noiu *et al*., 2016; Marra *et al*., 2009).

The amount of energy gained depends on frequency of the radiation, which is:

$\Delta E = h\vartheta$ and $E = hc/\lambda$ .... (7)

where:

Wavelength (λ); Frequency (ϑ); h=Plank's constant (6.34×10^{-3}); c=velocity of light (2.998×10^{8} m/s), (Smith, 2004).

Microwave dielectric heating is rapidly becoming an established procedure in artificial chemistry. (Gabriel *et al*., 1998). Microwave have specified standard frequency bands (915 MHz and 2.45 GHz). For a microwave ovens electromagnetic waves deployed at a frequency of 2.45 GHz (wavelength about 12 cm) (Datta, 2003), that make water molecules vibrate fast and heat up (Ştefănoiu *et al*., 2016). Microwaves can travel through glass and plastic and penetrate about a centimeter into food (depending on the food) but bounce off metal surfaces (Dibben, 2001). By placing food inside MW field the magnitude of field changed inside the cavity and some energy dissipated inside food. As foods are lossy material microwave energy is lost when converted into thermal energy (Datta, 2003). The skin depth (δ) is measure of how far fields will infiltrate. It is defined as depth at which the level of field has been attenuated to 1/e (=36.6%) of its value at the exterior of food materials (Dibben, 2001). The key issued with microwave heating of foods are magnitude of energy deposited by microwave and uniformity of energy deposition (Zhang and Datta, 2001). Also, it gives out deeper penetration in food, induce molecular friction in water and finally extent of heating depends on moisture content (MC) of food and heating is volumetric throughout the food (Gabriel *et al*., 1998). In microwave frequency field, water molecules attempt to align themselves with the changing (Ştefănoiu *et al*., 2016). Heat is generated as a result of intermolecular friction (Datta, 2003). The second mechanism of heating with microwaves is through the polarization of ions as a result of back and forth movement of ionic molecules trying to align themselves with the oscillating electric field. Basic theory underlying microwave dielectric heating is collated with the dielectric data for a wide range of solvents which are commonly used in microwave technology (Dibben, 2001; Gabriel *et al*., 1998).

In foods, firstly, it is extremely difficult to accurately and consistently measure moisture within dynamic processes. Second, moisture as a contaminant is capable of severely damaging any processes (Datta and Rakesh, 2013). Compared to microwave (MW) heating which involves higher frequency (2450 MHz), RF heating ensures more uniform heating and deeper penetration depth in solid and semi-solid low moisture foods due to the lower frequency range and longer wavelengths (Marra *et al*., 2009). But, the variation in temperature distribution of food during RF heating can lead to overheated hot area causing severe quality deterioration (Ştefa˘noiu *et al*., 2016).

Principal of operation of drying (dielectric model parameters). The technology is the results of scientific research of the solution of practical problems (BOARD, 2012). A technology is application of discovery or invention to practical ends (Lane and Flagg, 2010). Food industry uses energy in forms thermal, chemical, mechanical and radiant (Ananchaipattana *et al*., 2015). Energy is the capacity to do work and rate of heat energy transfer is much important (Kudra and Mujumdar, 2002). The technologies like infrared radiation heating/drying uses mechanism of heat transfer with thermal radiation involves direct impingement of radiation on the surface followed by conduction of heat inside of food product (Laguerre Jean-Claude and Agha, 2020).

Food science is concerned with the knowledge of physical, chemical and biological including nutritional, properties of food and their constituents and changes they undergo when subjected to handling, preservation, processing, storage and distribution (Ananchaipattana *et al*., 2015). Electromagnetic (EM) radiation in the infrared part of the frequency spectrum is directly absorbed as heat by most food stuff material (Laguerre and Agha, 2020). The termed "electromagnetic radiation" is because waves are radiating from the electrically charged particles (Křivánek, 2008). Radio waves (RF), microwaves, visible light and X-rays are all examples of electro-magnetic waves that differ from each other in wave length (Lumen, 2017b).

All metals reflect microwaves shield such that no waves escape but many semiconductor and insulating (dielectric) materials absorbed radiated microwaves falling by, generating a temperature rise inside it (Datta and Rakesh, 2013). Common to other heating methods, heat produced above the surface, which penetrates and conducts towards the centre, speed of energy dissipation and the depth of penetration being dependent on the composition of the substance or material available for heating (Laguerre and Agha, 2020). Microwaves can also heat-up us and can damage our skin cells (Kumar, 2015). Keep the cavity door closed when power-on and never use a damaged microwave oven. So, drying food is a simultaneous heat and mass transfer operation and made by heating up the water in the first cm or of the food (Aguilera *et al*., 2004). Moisture loss from the interior of foods during heating has normally been attributed solely to diffusion. Such diffusion take place by Fick's law which defines concentration gradient to be responsible for diffusion with in a food as continues medium (Kumar, 2015). Molecular or Ficken diffusion is widely used as general model for mass transfer in drying, leaching and frying (Aguilera *et al*., 2004), which is relate to recipes of the food stand, while to let the heat spread evenly. The total thermal input (combined time and temperature) is main factor rather merely heating rate for pasteurizing or inducing heat in food product (Datta and Rakesh, 2013). Microwave ovens use electromagnetic waves at a frequency of 2.45 GHz (wavelength about 12 cm) (Kumar, 2015), that make water molecules vibrate fast and heat up (Datta, 2003). Microwaves can travel through glass and plastic and penetrate about a centimeter into food (depending on the food) but bounce off metal surfaces (Laguerre and Agha, 2020). As a method of volumetric heating, radio and microwaves frequency heating offers the possibility to rapidly pasteurize (kills germs) in foods, while maintaining the food quality (Datta, 2003).

The dielectric ratio of material to dielectric properties of medium (free space) is the most important parameter (Tewari, 2007) and provides relative dielectric constant and relative dielectric loss factor (Ştefănoiu *et al*., 2016). The relative dielectric constant give out amount of incident power absorbed or reflected while dielectric loss factor indicates the amount of absorbed energy dissipated or transmitted with in food (Ştefănoiu *et al*., 2016; Marra *et al*., 2009). The loss fraction (from skin depth) or dielectric loss factor (tan δ) tangents of the solvents, which may be related to the ability of the solvent to absorb energy in a microwave cavity, depend on the relaxation times of the molecules (Datta, 2001). These relaxation times depend critically on the nature of the certain combination's functional groups (Dean, 1999) and the volume of the molecule. Functional groups capable of hydrogen bonding have a particularly strong influence on the relaxation times (Laguerre and Agha, 2020). Moisture content decreased linearly with drying time during microwave drying after about an initial period, the relaxation times of materials/solvents decrease as the temperature of the solvent is increase (Suzan *et al*., 2006).

Instrumentation. The EM spectrum shows infrared, visible, ultra violet, X-rays and gamma radiations Table 6, radio waves range from 3 KHz to 300 GHz. Electromagnetic radiations in the infrared part of the frequency spectrum is directly absorbed as heat by most things at or near the surface (Suzan *et al*., 2006).

The term "micro" means very small. It is a millionth (10^{-6}) part of a unit (Dean, 1999). The term microwaves are principally radio frequency (RF) waves, ranges from 300 MHz to 300 GHz. There are a number of permissible ISM (Industrial, Scientific and Medical) frequencies available for food heating use, where both domestic and catering microwave ovens are using the 2450 MHz±50 MHz (2.5 GHz) frequency waveband (Laguerre and Agha, 2020). When microwave energy impinges on a material, the energy absorbed and converted into heat inside product (Ştefănoiu *et al*., 2016). This penetration is inversely proportional to frequency (Marra *et al*., 2009). All microwave ovens create energy, not heat and interactions between the energy created and the different substances results in that heat (Datta, 2001). A magnetron is high frequency generator and transport energy by a hollow rectangular wave guide to an oven designed to prevent leakage of microwave energy. Additionally, invention of magnetron technology actually first fully developed for military radar systems (Famous, 2021; Wikipedia, 2021b).

Working principal. Microwaves have their frequencies very close to the vibration mode frequencies of water, microwaves excite those vibration modes of food in the oven and can heat up; as these water molecules agitated, they begin to vibrate at the atomic level and generate heat. This heat actually cooks food in the Microwave. Because all particles in the food are vibrating and generating heat at the same time, food cooked in the microwave cooks much more swiftly than food cooked in a conventional oven. Prolonged exposure would result in more heat which is definitely harmful to cook (Fung and Sheree, 1984). All our concerned in cooking, as a shifting of food from raw to cook. Individual component shape and consistency, evenness of meal component size, liquid content and viscosity, are all important factors in this respect. Further to oven performance, it is the shape and overall presentation of the product which influences heating process, and thereby provides an evenly heated result. Microwave cooking is fundamentally different from other ways in that it adds heat directly to the inside of the stuff. All forms of cooking raise the temperature, thereby allowing some chemical changes to happen. Chemical changes may happens inside food, a microwaves oven, firstly produces Microwave electromagnetic radiation that is complying with resonates frequency of water molecules. The water molecule inside food absorbed energy and passes some conduction to nearby food stuff which makes the stuff hotter. It might consider that salt, sugar and fat are three of the most microwave reactive ingredients likely to be used in a microwave food products. Salt drastically averaged microwave penetration and consequently, salt reduction would potentially increase energy penetration depth. For instance, using the same method, the penetration depth into filtered water at ambient temperature is approximately 11 mm, if only supplied by 1% salt which is reduces to 5 mm (and 2 mm if salt percent upto 5%). Conversely, the removal of salt aids energy dissipation and allows deeper penetration. Also, sugar is a very good absorber of microwave energy. For example, high sugar jam or fruit-filled pie fillings can easily reach temperatures sufficient to burn a person's mouth, even though the pastry exterior may appear relatively cold. However, sugar mostly used to balance the heating effects of poor microwave absorbing food material and components within microwaveable deserts and puddings (Andrews, 1987).

Most good quality microwave oven suggests that to minimize the effects of localized food burning (sometimes sparking under frozen conditions), add some seasoning after heating and the dehydration of green vegetables, commonly experienced due to the energy being more concentrated at the food's exterior. Fats and oils are poor absorbers of microwave energy but fortunately, having a relatively low specific heat capacity, requiring less energy to raise their temperature.

Conclusion

Chilled foods have been available since the 1960s. Shelf life represents the useful storage life of food, determined by changes in taste, smell, texture, appearance that are un-acceptable or undesirable. Thermal pasteurization is currently the major method to extend the shelf-life of food products. A conflict between product functionalities and shelf life of functional foods has been long under investigation by researcher. Food processing contaminants are present in many different foods at relatively low amounts, usually in the part/billion range (PPB). Consequently, the analytical methods to detect these contaminants are usually based on mass spectrometry, with a gas chromatographic or liquid chromatographic step to ensure adequate separation.

Researchers have been trying to developed alternative technologies to thermal processing to protect the functional components from being destroyed, as functional components in foods play important role in maintaining the health of humans (like plant proteins are beneficial to human health). A conflict between product functionalities and shelf life of functional foods have been long under investigation by researcher. The underlying causes of these changes may be microbiological, chemical, or physical. Bacteria, mould and yeast cause bio-deterioration spoilage. Almost all groups of micro-organisms under some conditions can contribute to spoilage of foods. Bacterial growth on food changes, as it passes through a succession of stages. Microbiologists support bacteria counting on the assumption that one single bacterium can give rise to one colony on solid media and called as a colony forming unit (Cfu for short). Therefore, the shelf life of specific food product in terms of bacterial spoilage now, defined as the time required by the spoilage micro-organism to reach maximum density of cells. Therefore, the shelf life basically represents the lag phase-time (sometime is required to prepare for the growth) and the time required by the bacterium during the growth rate to reach maximum density. For risk assessment of foods and food ingredients, it is desirable to identify possible toxic compounds also on the basis of their chemical structure and mechanism of action. Moreover, the determination of risk level of food security is an important problem and related to supply chain environment. The food security is defined as the access of all the peoples to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Food security covers a wide area and is characterized by a set of different factors.

Conflict of Interest. The authors declare that they have no conflict of interest.

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