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THE FACTORS INFLUENCE MICROBIAL CONTAMINATION IN RELATION TO WATER ACTIVITY, AFLATOXINS AND FOOD BORNE DISEASES IN MBEYA CITY, MBEYA REGION, TANZANIA

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ABSTRACT

The study sought to explore the status of microbial contaminants in street vended food and the incubatory carriers among street food vendors conducted in Mbeya City in 2014. The questionnaires and observation checklists were administered whereas, bacteriological examination of stool specimen and food were collected from 96 street food vendors. The results showed that 21 (27%) out of 78 of food samples collected and five out of 25 stool specimens were found with food borne disease pathogens. Some of the pathogens are not only among the top ten least wanted food borne diseases but also some vendors were convalescent carrier and multidrug resistant. The pathogens include *Escherichia coli* O157: H7, *Staphylococcus aureus, Salmonella* Typhi and *Salmonella* Typhimurium. The results showed that 70% of respondents had formal primary education, 27% had secondary school education, 1% had university education suggesting that majority of vendors never had basic knowledge on food safety training to better understand the concept of the food safety in relation to microbial contamination in food and human health carriers. The results of microbial quality of the food demonstrated that the food vendors had to offer unsafe food to their clients. The study identified infrastructure, food equipment, casual helpers, presence of pests, holding temperature for food and storage, weak regulatory systems as a gap in Mbeya City Council. The outcome of this study can serve as a baseline data for management and improvement of the street food safety based on study area.

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INTRODUCTION

The study was carried out on street food vendors and their food they sold in the City of Mbeya. The study based on four wards Ruanda, Sisimba, Uyole, and Igawilo in the City Mbeya. The study involves the application of two tools: the WHO five keys to safe food and five keys to growing safe fruits and vegetables. As microbiological the five keys aimed at safeguarding food hygiene practice and promoting health by decreasing microbial contamination from food vendors and street vended food. The keys are 1) Keep Clean; 2) Use safe; raw materials and water 3) Cook food thoroughly; 4) Avoid cross contamination and 5) "Keep food at safe temperatures. The five keys practices presented in the paper aim at reducing microbial contamination resulting from biological, therefore do not address contamination by chemical or other hazards. However, the knowledge and technologies that can eliminate all food safety problems associated with the microbial contamination of food are not yet present (WHO, 2012). Microbiological, Physical and chemical hazards are of disquiet. Among biological hazards, the contamination of foodstuff and/or feed by aflatoxins by plant species by their plant toxins have been recently characterized by many countries the world over as significant sources of food-borne illnesses. However, regulations have been established in many countries to protect consumers from the harmful effects of aflatoxins that may contaminate foodstuffs, as well as to ensure fair practices in food trade. The paper presents the new tool that practices to reduce microbial contamination of fresh fruits, vegetables, and cereals from fungal i.e. mycotoxins, during planting, growing, harvesting and storing. The Five keys are: 1) Practice good personal hygiene; 2) Protect fields from animal faecal contamination; 3) Use treated faecal waste; 4) Evaluate and manage risks from irrigation water and 5) Keep harvest and storage equipment clean and dry. Some microbial such aflatoxins can produce moulds, smell and/or discolorations while, others organisms hardly real produce any smell, discoloration, or any other changes you can detect with your senses. In addition, you will not even know they are there until you start to feel nauseous, stomach cramps or pain. The Keys have been practice by countries such Belize, Guatemala, and El Salvador (WHO, 2012 & WHO, 2016). In addition, the outbreak of Aflatoxicosis in Tanzania July to December 2016 of which 68 cases and 20 deaths Case Fatality Rate of 29.41% occurred and found reported by Aflatoxicosis Situation

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Updates and Response WHO Country Office, Tanzania on 11 January 2017. The affected regions were Dodoma and Manyara; this resulted from the poor production of peanuts and maize not kept in clean and dry storage equipment, poor food safety and improper handling of food (Zain, 2011 & Nelson & Zeratsky, 2012). The Aflatoxins according to Yard *et al*., (2013) are a fungal toxin that derived from some strains of *Aspergillus flavus;* they reported to taint an estimated one-quarter of agricultural products worldwide, with maize, cereals, and groundnuts being the most predisposed. This can be mitigated by application of five keys to growing safe fruits and vegetables as the case of Belize, Guatemala, and El Salvador (WHO, 2012 & WHO, 2016).

Factors that offer Microbial Growth in Food

In generally most food contains sufficient nutrients to support microbial growth of which several factors encourage, prevent, or limit the growth of microorganisms in food; the most important are moisture, temperature, time, Oxygen, and pH. These factors are broadly involved water activity, pH, temperature, and relative humidity. The water activity varies very little with a temperature that supports microbial growth. The addition of solute decreases the water activity to less than one. The change in pH of a food with time may reflect microbial activity, and food that is poorly buffered does not resist changes in pH, such as vegetables, may change pH values (Yusuf *et al*., 2012). Example for the pH of muscle from a rested animal may differ from that of a fatigued animal. Occasionally, food pH is not stationary; sometimes-other microbes' yeasts or moulds, pH may change and allow bacterial growth. The pH range of a microorganism is at the acidic while a maximum is at the basic end of the scale. Growth is maximal for a pH optimum; the most favorable conditions are time, temperature, pH, and incubation period that every microorganism has a minimum, an optimum and a maximum pH for growth. Moving away from the pH optimum in either direction slows down microbial growth (Yusuf *et al*., 2012). The greatest danger from microbes in food is associated with consumption of various sources of food that is mainly tainted with human and animal faeces, and other factors may encourage, prevent, or limit the growth of microorganisms in food. The water activity, pH, and temperature may also be important. This paper focuses on organisms for which there is evidence, from outbreak studies or from prospective studies in non-outbreak situations, of disease being caused by ingestion of unsafe food. Risk factors associated with the human reason and preparation methods that give high prevalence of food borne diseases shown by various studies. The widespread food borne pathogens that linked to that danger include *Campylobacter Jejuni, Clostridium botulinum, perfringens*, *Escherichia coli* O157: H7, *Listeria Monocytogenes, Salmonella, Shigella*, *Vibrio cholera*, Hepatitis "A", Norovirus, *Cyclospora cayetanensis, Staphylococcus aureus, Campylobactor jejuni* and *Toxoplasma gondii* (TEA, 2015). The hazard causes included improper holding temperatures, inadequate cooking, contaminated equipment, storage, food from an unsafe source and poor personal hygiene (Chilukoti, 2014).

Vendors food borne disease pathogens carrier status

Twenty-five human stool specimens were drawn from the four wards Ruanda, Sisimba, Uyole, and Igawilo showed that only five and specifically those drawn from Ruanda ward were contaminated with food borne diseases pathogens often implicated in diarrhoeal diseases. These include *Escherichia coli* O157: H7, *Staphylococcus aureus, Salmonella* Typhi and *Salmonella* Typhimurium that are not only among the 16 known food borne disease pathogens listed in Table 2 but also the top ten least wanted in food as they are known to fatal consequences to consumers of food the contaminated food. According to Thanh, (2015) *Salmonella* species, *Escherichia coli,* and *Staphylococcus Aureus* are antimicrobial-resistant pathogens bacteria. These included two isolates of *Salmonella* Typhi, one isolate of *Escherichia coli* 0157: H7, one isolate of *Escherichia coli* species*,* and one isolate of *Salmonella* Typhimurium.

In the study area, the most spread pathogens among the isolates were *Salmonella* species at 60% i.e. three-fifth of all isolates. However, no single stool sample food with more than one pathogens or with co-infections as some pathogen species may interact within the host (Diedrich, 2011). This anticipated that future studies might clarify valuable new information on the interesting subject of co-infection of protozoa with other pathogens. The carrier status is evidence that no food hygiene regulation was been complied with during the time of the study.

Table 1. Pathogens isolated in collected stool specimen

SN	Ward	Isolated Pathogen
$A_1$14	Ruanda	*Escherichia coli* 0157: H7*
A_1-17	Ruanda	*Escherichia coli*
A_1-03	Ruanda	*Salmonella* Typhi*
A_1.16	Ruanda	*Salmonella* Typhimurium*
B_2.16	Sisimba	*Salmonella* Typhi*

Source: Field data collected in 2014 by Authors

Note: i) Reading machine: BBL-Crystal Auto reader: cat. no.245300 (BD, 2013)

ii) Isolates are taxonomically annotated

*List of top ten least wanted food borne pathogens: *Campylobacter, Clostridium botulinum, Escherichia coli* O157: H7, *Listeria monocytogenes, Norovirus, Salmonella, Staphylococcus aureus, Shigella, Toxoplasma gondii,* Vibrio vulnificus (TEA, 2012 and CFIA, 2016)

Microbiological contaminants in food

Of 78, various food samples collected 21 (27%) had pathogens that can cause food borne diseases as shown in Table 2). These findings were somehow similar to several study findings by Campbell in (2011) South Africa; Schmidt in (2011) Canada; Githaiga in 2012 & Nyamari in (2013) Kenya; Tiisekwa in (2013) Tanzania. The similar studies conducted in Tanzania include that of Njaya in (2013) Zimbabwe; Samapundo (2013) in Haiti; Ntomola in (2014) Tanzania; Omemu *et al.*, in (2014) Nigeria; Girma in (2015) Ethiopia; Thanh in (2015) Vietnam. One sample of sardines and cooked rice had *Staphylococcus aureus* 3% two out of 78. *Escherichia coli* were isolated in two samples of cooked rice and in a sample of pickle-mixed vegetables. *Bacillus cereus* was isolated in a sample of cooked maize mixed with beans and lastly, *Enterobacter cloacae* were isolated in one cooked liver sample. In the other circumstance, two pathogens *Acinetobacter baumannii* and *Acinetobacter haemolyticus were found in a* cooked bean while *Bacillus megaterium* and Lactococcus raffinolactis found in a stiff porridge sample. This is contrary to the stool sample that single pathogen found in a stool sample presents no co-infection. As the case of parasite interactions that include microbial interference when one bacterial species can further

suppress the virulence or colonization of other bacteria, such as *Pseudomonas aeruginosa* suppressing pathogenic *Staphylococcus aureus* colony formation revealed by (Sievert *et al*., 2013). Of all isolates, only bacterial pathogens were isolated. Pathogens like viruses, protozoa, and helminths, which are commonly responsible for causing diarrhoeal diseases, were not isolated from the sample collected in the study area. According to Acharya, (2012 & 2015) indeed the above limitation was expected because of the laboratory capacity and specialty. Abdalla *et al*. (2009); Kok & Balkaran (2014) suggest that in food processing, food borne microbes can be introduced from an infected person who handles the food, or by cross contamination from some other raw agricultural products and/or the in-plant environment. Abdalla *et al*. (2009); Kok & Balkaran (2014), they further emphasize that contaminated hands are the most significant source of transfer microorganisms from food handler's faeces, face, skin, or other sites on to food. *Escherichia coli, Salmonella* species*, Escherichia coli* 0157: H7, *Staphylococcus aureus,* and *Enterobacter Cloacae* are potential food borne hazards with grave consequences.

specialty. Only (6%) five out of 78 samples were drawn from food that found kept at the optimal temperatures of 63°C. In principle, one must apply thermometers to make sure that the temperature of the refrigerator is 40°F or lower and the temperature of the freezer is 0°F or less. Canadian Food Inspection Agency (CFIA, 2016) demonstrates that bacteria can grow in the danger zone between 4°C and 60°C (40°F to 140°F). While, raw food such as veal steaks, chops, and roasts should be cooked to a least an internal temperature of 63°C to 74°C and 85°C (145°F to 165°F and 185°F) for a whole chicken, turkey, and duck (CFIA, 2016). This suggests that there was poor food holding and storage temperature that can facilitate the microbial growth.

Summarising Table 1: above it may be stated that, (20%) five out of 25 pathogens isolated in vendors' stool specimens and 27% (21 out of 780) food samples are among the top 10 public health pathogens of importance in food safety. These pathogens are known to cause serious food poisoning according to (CFIA (2016); Adem *et al*. (2008); Khanjar & Alwan (2014). The carrier status in Ruanda ward and the wide

Table 2. Pathogens isolated in various food samples

Sample code	Ward	Food Types	Isolated pathogen
A_2-12	Ruanda	Cooked liver	*Enterobacter cloacae*
B_2-04	Sisimba	Cooked beans	*Acinetobacter baumannii* and *Acinetobacter haemolyticus*
B_2-04	Sisimba	Stiff porridge (Ugali)	*Bacillus megaterium* and Lactococcus raffinolactis
B_2-07	Sisimba	Chicken	*Staphylococcus intermedius*
B_2-23	Sisimba	Cooked maize with beans	*Bacillus cereus*
C_2-10	Uyole	Cooked rice	*Escherichia coli*
C_2-06	Uyole	Pickles (raw vegetable mixed)	*Escherichia coli*
B_2-16	Sisimba	Mandazi (African buns)	*Enterobacter asburiae*
B_2-15	Sisimba	Porridge	*Escherichia coli*
D_2-11	Igawilo	Cooked pork soup	*Klebsiella oxytoca*
C2-17	Uyole	Sour milk	*Hasnia alivei*
A_2-02	Ruanda	Rice	*Escherichia coli*
A_2-10	Ruanda	Pickles (raw vegetable mixed)	*Enterococcus faecium*
A_2-25	Runda	Chips	*Klebsiella pneumoniae*
A_2-22	Ruanda	Sardines	*Staphylococcus aureus**
A_2-27	Ruanda	Sour milk	Yeast cells
C_2-20	Uyole	Rice	*Staphylococcus aureus**
C_2-16	Uyole	Juice	*Enterobacter aerogenes*
A_2-19	Ruanda	Meat/fish	*Corynebacterium bovis*

Source: Field data collected in 2014 by Authors.
Note: i) Reading machine: BBL-Crystal Auto reader: cat. no. 245300 (BD, 2013)
ii) Isolates are taxonomically annotated
*List of top ten least wanted food borne pathogens:
Campylobacter, Clostridium botulinum, Escherichia coli O157: H7, *Listeria monocytogenes, Norovirus, Salmonella, Staphylococcus aureus, Shigella, Toxoplasma gondii* and Vibrio vulnificus, (TEA, 2012 and CFIA, 2016).

Salmonella species, which is about 2 to 5% of untreated typhoid infections or those survivors of typhoid, can become chronic carriers and stand as a continuous spread (Ahmed, 20017). The frequency of occurrence of isolated pathogens in food suggests that consumers in Mbeya City were exposed to high risk of contracting diarrhoeal diseases through consumption of some street food cuisines. On the Other hand, other options suggested that to educate the consumers not to buy street food that sold in unauthorized places simply because of convenience or low pricing. Additional macro and microorganisms often found in food were not isolated not necessarily, because they were absent but because they were not targeted by the methods used for analysis in this study (FDA, 2012; Neza & Centini, 2016). For this reason, the relative proportions of pathogenic to non-pathogenic strains in the study area are unknown. Some of these bacteria are associated with food spoilage *Klebsiella oxytoca* and Yeast cells (Sperber & Doyle, 2009 & FDA, 2012). Indeed the above limitation was expected because of the laboratory capacity and

spread confirmation of food contaminated with food borne microbes in the study area shows that there is a potential risk for diarrhoeal diseases outbreaks in Mbeya City and particularly in Ruanda ward. The infected vendors may have been victims of an earlier outbreak who came back to vending food without full recovery followed by non-clearance by a reliable medical examination protocol or were new comers who may get into food vending business while infected. In this case, they both should have been cleared by a reputable and reliable medical examination before engagement, as the law requires. On the other hand, they may have been victims of an ongoing outbreak in Mbeya City or elsewhere that was yet to become publicly noticeable. In both cases, it shows a gap within the City Health Authorities pro-activeness in food hygiene protocols and needs to be redressed. The fungal toxins that produce *Aspergillus flavus* found mainly in maize, cereals, groundnuts by cooking can withstand the high temperature of more than 180^{o}C (Yard *et al*., 2013). However, aflatoxins in food can be control best achieved by measures designed to

prevent the contamination of crops in the field and during storage, or detection and removal of contaminated material from the food supply chain. These fungal toxins that produce *Aspergillus flavus* are responsible for aflatoxicosis outbreaks in East Africa countries including Kenya and recently Tanzania of which 68 cases and 20 deaths. The affected regions were Dodoma and Manyara; this resulted from the poor production of peanuts and maize not kept in clean and dry storage equipment, poor food safety and improper handling of food (Zain, 2011; Nelson and Zeratsky, 2012).

The Aflatoxins according to Yard *et al*. (2013) are a fungal toxin that derived from some strains of *Aspergillus flavus;* they reported to taint an estimated one-quarter of agricultural products worldwide, with maize, cereals, and groundnuts being the most predisposed. This can be mitigated by application of five keys to growing safe fruits and vegetables the case of Belize, Guatemala, and El Salvador (WHO, 2012 & WHO, 2016). The experience of Belize, Guatemala, and El Salvador in successful adaptation of these keys may be suitable for controlling aflatoxicosis in Tanzania and other settings with similar nature. While in the case of cholera, the adaptation which, will suit cholera setting by training food street vendors, school children, and community on five keys to safe food, this has worked in Haiti, Comoros, Angola, Gambia, Mozambique, Guinea, Botswana and the Democratic Republic of Congo is useful. Controlling microbial growth in food is not a once and all activity it needs multi-interventions that start from farm to dinning. The mnemonic conditions such moulds and others forcing the monitoring being throughout food supply chains to final consumers.

contamination can occur in many different ways. Four main causes of food contamination are not washing hands, cross-contamination as the process of transferring contaminants from one food contact surface to another improper storage and cooking temperatures and/or contamination by animal wastes. The contaminants can be divided into three categories: physical, chemical, and biological, demonstrated in Table 4. This paper is based mainly on biological aspects that microbes are responsible for a large number of food borne diseases.

The threat of Aflatoxins to humans, mammals, fish and birds

Aflatoxins are highly toxic compounds and can cause both acute and chronic toxicity in humans, mammals, fish, and birds (Lawley, 2013). Their importance was first recognized in 1960 when 100,000 turkeys and other poultry in the UK died in a single incident. The cause of this was traced back to a toxic contaminant in groundnut meal used in the bird's feed. The aflatoxins consist of more than 20 similar compounds, but only four are physically found in food. The umbrella term aflatoxin refers to four different types of mycotoxins produced, which are B_1, B_2, G_1, and G_2 (Yin *et al*, 2008). Aflatoxin B1 is the most commonly found in food and the most ever found toxic. When lactating cattle and other animals ingest aflatoxins in contaminated feed that is toxic metabolites can be formed and may be present in milk. These metabolites, aflatoxin M1 and M2, are potentially important contaminants in dairy products as they shift the toxic from animal product milk to human, even if bread, biscuits and other product made from such milk may be at risk. Aflatoxins may be present in a wide range of

Table 3. Water activity (a_w) value for microbial growth

Food poisoning organisms	Water Activity (a_w)	Food Borne Infectious Organisms	Water Activity(a_w)
Clostridium botulinum A	0.95	*Clostridium perfringens*	0.95
Clostridium botulinum B	0.94	*Escherichia coli* 0157: H7	0.95
Clostridium botulinum E	0.97	*Vibrio cholera*	0.95
Bacillus cereus	0.95	*Salmonella* species	0.94
Campylobacter coli	0.95	Vibrio parahaemolyticus	0.94
Campylobacter jejuni	0.98	Yersinia enterocolitica	0.96
Listeria monocytogenes	0.92	*Aspergillus flavus*	0.82
Staphylococcus aureus	0.86		

Source: Adapted from (Bennett *et al.*, 2013 and Kadariya *et al*., 2014)

Table 4. Biological, chemical, and physical hazards contaminants

S.N.	Types	Contamination hazards
1)	Biological	Pathogenic bacteria, e.g. *Escherichia coli* 0157: H7, *Salmonella* species, usually associated with faecal contamination from warm-blooded animals, or others, e.g. *Listeria monocytogenes*, *Clostridium botulinum* commonly found in contaminated soil, water, and ruminants
		Naturally occurring plant toxins, e.g. alkaloids, cyanogens glycosides
		Fungal, e.g. ergot, mycotoxins such as aflatoxins and ochratoxins
		Parasites, e.g. Cyclospora, Entamoeba, Giardia, Cryptosporidium
		Viruses, e.g. hepatitis A, Norwalk virus, Rotavirus
		Neurodegenerative disease e.g. prions cause Bovine spongiform encephalopathy (BSE, or "mad cow disease" is a prion disease in cattle
2)	Chemical	Pesticide, insecticide and fungicide residues (international food law includes maximum residue levels for named compounds to be used on specific fruit and vegetables)
		Heavy metals, e.g. zinc, lead, aluminum, cadmium, and mercury
		Mineral oils, e.g. diesel, grease, hydraulic oil
3)	Physical	Glass, metal, stones
		Wood and twigs
		Pieces of bone and plastic
		Staple wire, hair, and dust

Source: Types food contaminants adapted from Texas Education Agency (2014) & (2015)

Sometimes food we feel affection for and count on for good health are contaminated with microorganisms that cause sickness and can be deadly for certain people. Food

food commodities, particularly cereals, oilseeds, spices, tree nuts, maize, groundnuts chilies, black peppers, dried fruits and many others may all known to be of high risk foods for

aflatoxin contamination, but the toxins have also been detected in many other commodities. Milk, eggs, cheese, meat and other products are sometimes contaminated because of the animal consumption of aflatoxin-contaminated feed. Aflatoxins can cause acute toxicity, and potentially death, in mammals, birds, and fish, as well as in humans. The liver is the principal organ affected, but high levels of aflatoxin have also been found in the lungs, kidneys, brains, and hearts of individuals dying of acute aflatoxicosis. Acute necrosis and cirrhosis of the liver are typical, along with hemorrhaging and oedema. Aflatoxin B1 is a very potent carcinogen and a mutagen in many animals, and therefore potentially in humans, and the liver is again the main target organ (Lawley, 2013). Ingestion of low levels over a long period has been implicated in primary liver cancer, chronic hepatitis, jaundice, cirrhosis, and impaired nutrient conversion. Aflatoxins may also play a role in other conditions, such as Reye's syndrome and kwashiorkor a childhood condition linked to malnutrition. Less is known about the chronic toxicity of aflatoxin G1 and M1, but these are also thought to be carcinogens, though probably a little less potent than B1. Acute human aflatoxicosis is rare, especially in developed countries, where contamination levels in food is monitored and controlled. However, there have been outbreaks in some developing countries, especially in sub-Saharan Africa, where maize and groundnuts can be an important part of the diet and where the climate is suitable for rapid mould growth on crops in the field and in storage. A notable outbreak occurred in India in 1974 when almost 400 people became ill with fever and jaundice after eating maize contaminated with between 0.25 and 15 mg/kg aflatoxin and more than 100 died. Major outbreaks have also occurred in Kenya, the largest in 2004 when 317 people were affected and 125 died, probably because of eating contaminated maize and the recent outbreak which occurred Dodoma and Arusha regions in 2016 Tanzania about 68 cases and 20 deaths.

Aflatoxins Species

Aflatoxins are produced by at least three *Aspergillus* species. These are *A. flavus*, *A. parasiticus* and the much more rare *A. nomius*. These molds are able to colonise a wide range of crops both in the field as non-destructive plant pathogens and in storage, and can grow and produce aflatoxins at quite low moisture levels at approximately minimum A_w 0.82) and over a broad temperature range from 13-37^oC. Their growth is strongly influenced by climate and they are more common in tropical regions with extreme variations in temperature, rainfall and humidity. *A. flavus* invasion of groundnut crops in the field is known to be favoured by drought stress and maize crops are vulnerable if damaged by insect pests. Mould growth and aflatoxin production during storage of crops is also important, especially if drying is inadequate, or storage conditions allow access for insect or animal pests. Aflatoxins are quite stable compounds and survive relatively high temperatures with little degradation. Their heat stability is influenced by other factors, such as moisture level and pH, but heating or cooking processes cannot be relied upon to destroy aflatoxins. It is greatly resist decomposition or being broken down in digestion, so they remain in the food chain in meat and dairy products (Adejumo and Adejoro, 2014). Even temperature treatments, such as cooking and freezing, do not destroy some mycotoxins. For example, roasting green coffee at 180^oC for 10 minutes gave only a 50% reduction in aflatoxin B_1level. The stability of aflatoxin M_1 in milk fermentation processes has also been studied and although appreciable losses do occur, significant quantities of the toxin were found to remain in both cheese and yoghurt.

Control of Aflatoxins

Aflatoxins in food the control can be best achieved by measures designed to prevent the contamination of crops in the field and during storage, or detection and removal of contaminated material from the food supply chain. Pre-harvest control of aflatoxins is best achieved through general Good Agricultural Practice (GAP) to include such measures as: 1) Land preparation, crop waste removal, fertiliser application and crop rotation. Others are 2) Use of fungus- and pest-resistant crop varieties 3) Control of insect pests; 4) Control of fungal infection; 5) Prevention of drought stress by irrigation and 6) Harvesting at the correct moisture level and stage of maturity. The most important and effective control measure in post-harvest handling and storage is the control of moisture content and hence, the water activity of the crop. Ensuring that susceptible crops are harvested at a safe moisture level, or are dried to a safe level immediately after harvest is vital to prevent mould growth and aflatoxin production during storage. The safe moisture level varies between crops, for maize it is approximately 14% at 20^oC, but for groundnuts, it is much lower, about 7%. These moisture levels must be maintained during storage and transport (Wild and Gong, 2010). In Food Safety and Sanitation Class, six conditions suggested by Texas Education Agency (TEA, 2014 & 2015) which bacteria may need to grow, its acronymically is abbreviated as "FAT TOM" it stand as Food, Acidity, Temperature, Time, Oxygen, and Moisture. FAT TOM is a mnemonic device that portrayed in Table 5 is used in the food service industry to describe the six factors that contribute to food spoilage, favourable conditions required for the growth of food borne pathogens (TEA, 2015). In one extreme, these organisms do not real produce any smell, discoloration, or any other changes you can detect with your senses. You will not even know they are there until you start to feel nauseous, stomach cramps or pain.

The theory of Water Activity (a_w) and food borne diseases

The physical property of Water Activity (a_w) has direct influences on food storage stability because of some deteriorate processes in food are mediated by water. The chemical potential of (a_w) is related to the osmotic pressure of an aqueous solution. When a substance such as salt is dissolved in water, the water activity is reduced (Sevenich *et al*., 2015). Curing food with salt and sugar can also dispossess bacteria of the water they require. This is done through osmosis process. When applied to a food's external, salt and sugar pull moisture from the inside of the food to the surface, where it evaporates. Salt and sugar also bring on osmosis with the bacteria themselves by sucking the water out of them through their own cell walls, killing them by sunstroke. On the other hand, heat up food to 165°F 74°C or for at least 30 seconds is enough to wipe out any dangerous bacteria it might contain. This is why salting is an ancient way of preserving food. The water activity is the amount of moisture in food that activates the bacteria growth. The formula term of (a_w) is the ratio of the water vapour pressure of the food or solution (p) to that of pure water (po) at the same temperature: [a_W= p/po] (Sevenich *et al*., 2015). The water activity scale ranges from 0 to 1 as shown in Table 3. It suggested that the higher the value, the most available moisture in the food.

Table 5. The six conditions that promote the growth of foodborne pathogens

Mnemonic	Conditions	Narration of factors
F	Food	There are sufficient nutrients available that promote the growth of microorganisms. Protein-rich foods, such as meat, milk, eggs and fish are most susceptible to pathogens
A	Acid	Foodborne pathogens require a slightly acidic pH level of 4.6-7.5, while they thrive in conditions with a pH of 6.6-7.5. The United States Food and Drug Administration's (FDA) regulations for acid/acidified foods require that the food be brought to pH 4.5 or below.
T	Temperature	Food-borne pathogens grow best in temperatures between 41 to 135 F (5 to 57 C), a range referred to as the temperature danger zone (TDZ). They increase in temperatures that are between 70 to 104 F (21 to 40 C).
T	Time	Food-borne pathogens grow best in temperatures between 41 to 135 F (5 to 57 C), a range referred to as the temperature danger zone (TDZ). They increase in temperatures that are between 70 to 104 F (21 to 40 C).
O	Oxygen	Almost all foodborne pathogens are aerobic, that is requiring oxygen to grow. Some pathogens, such as *Clostridium botulinum*, are anaerobic requiring no oxygen.
M	Moisture	Water is essential for the growth of foodborne pathogens; water activity (a_w) is a measure of the water available for use on a scale of 0 to 1.0. Foodborne pathogens grow best in foods that have (a_w) between 0.95 and 1.0. FDA regulations for canned foods require a_w of 0.85 or below.

Source: Texas Education Agency (2014 & 2015).

Table 6. Persistence time of various pathogenic bacteria on dry inanimate surfaces

SN	Type of bacteria	Duration of persistence on dry surfaces
1	*Acinetobacter* spp.	3 days to 5 months
2	Bordetella pertussis	3 – 5 days
3	Campylobacter jejuni	Up to 6 days
4	Clostridium difficile (spores)	5 months
5	Chlamydia pneumoniae, Chlamydia trachomatis	≤ 30 hours
6	Chlamydia psittaci	15 days
7	Corynebacterium diphtheriae	7 days – 6 months
8	Corynebacterium pseudotuberculosis	1–8 days
9	Escherichia coli and Escherichia coli 057: H7	1.5 hours – 16 months
10	Enterococcus spp. including VRE and VSE	5 days – 4 months
11	Haemophilus influenza	12 days
12	Helicobacter pylori	≤ 90 minutes
13	*Klebsiella* spp.	2 hours to > 30 months
14	*Listeria* spp.	1 day – months
15	Mycobacterium bovis	> 2 months
16	Mycobacterium tuberculosis	1 day – 4 months
17	Neisseria gonorrhoeae	1 – 3 days
18	Proteus vulgaris	1 – 2 days
19	Pseudomonas aeruginosa	6 hours – 16 months; on dry floor: 5 weeks
20	Salmonella typhi	6 hours – 4 weeks
21	Salmonella typhimurium	10 days – 4.2 years
22	*Salmonella* spp.	1 day
23	Serratia marcescens	3 days – 2 months; on dry floor: 5 weeks
24	*Shigella* spp.	2 days – 5 months
25	Staphylococcus aureus, including MRSA	7 days – 7 months
26	Streptococcus pneumoniae	1 – 20 days
27	Streptococcus pyogenes	3 days – 6.5 months
28	Vibrio cholerae	1 – 7 days
Type of fungus		Duration of persistence on dry surface
1	Candida albicans	1 – 120 days
2	Candida parapsilosis	14 days
3	Torulopsis glabrata	102 – 150 days

Source: Modified from Kramer *et al*. (2006) & Lim *et al*. (2010)

Note: i) spp. = Species; VRE= vancomycin-resistant *Enterococcus*; VSE = vancomycin-sensitive Enterococci; MRSA= Methicillin-resistant *Staphylococcus aureus*

ii) Italic Roman typefaces are presented in taxa annotation

Water activity is a major reason for preventing or limiting the growth of bacteria causing food borne diseases. Food borne pathogens cannot grow under water activity of 0.85. In Table 3, almost listed food borne pathogens have water activity above 0.92 with exception of *Staphylococcus aureus* 0.85 and aflatoxin such as *Aspergillus flavus* 0.82 have water activity below 0.86. The various pathogens are critical and fatal in the prevention as some are listed in Table 3. Many of these pathogens have the different duration that can persist on dry inanimate object surfaces that can span for more than five years. Therefore, it is difficult to realize the risk of contamination of some diseases as when and where the risk occurred. This complexity can be from farm to dinning. It is important for everyone, include vendors and consumers to be aware of microbial risks along the food chain before eating to reduce the risks surrounding all the time although as some pathogens may be spread beyond the compliance of five keys to safe food and five keys to safer fruits and vegetables (Lim *et al*., 2010 and WHO, 2012). In the context of inanimate dry surfaces, some pathogens have high touch, surfaces that require a more frequent cleaning regimen. These are not limited to walkway rails doorknob/handle, walkway rails, beds, chairs in patient rooms at health care facilities. These surfaces have high risks of bioburden if not sterilised as it contains a high number of bacteria living on a surface compared to conference rooms, bus seats, communal and public places these have less potential for exposure to pathogens (Sehulster *et al*., 2004).

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