NUTRITIONAL QUALITY ASSESSMENT AND SAFETY EVALUATION OF FOOD CROPS

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Abstract. In sustained and consistent efforts to improve food security, numerous and different methods are proposed and used in the production of food crops and farm produce to meet the demands of consumers. However, unregulated, and indiscriminate methods of production present another problem that may expose consumers of these food crops to potential health risks. Therefore, it is imperative that a thorough assessment of farm produce is carried out due to the growing trend of health-conscious consumers preference for minimally processed or raw farm produce. This study evaluated the safety and nutritional quality of food crops. The objectives were to compare the nutritional quality of organic and conventional food crops in one hand, and on the other to evaluate the safety of food crops with respect to trace metal pollutant and relevant public health pathogenic microorganism contamination. We conducted a broad systematic search of peer-reviewed published literatures from databases and search engines such as Google Scholar, PubMed, ScienceDirect, Scopus, and Web-of-Science. This study concluded that there is no conclusive evidence to support the notion of nutritional superiority of organic food crops over their inorganic counterparts and that there are documented health risks associated with food crops irrespective of the types of production systems.
Keywords: *food crops, microbial pathogen, nutritional quality, trace metals, mycotoxins*

Introduction

According to the United Nations Department of Economic and Social Affairs, Population Division (2022), the world's population is more than three times larger than it was in the mid-twentieth century, reaching 8.0 billion in November 2022 from an estimated 2.5 billion people in 1950, and expected to reach 9.7 billion by 2050. This astronomical increase in human population and other anthropogenic activities which include industrial revolution and urbanization have become a major issue in the prospect of attaining food security. The growing population means that there must be a corresponding increase in the production of food crops, but anthropogenic activities have resulted in declining land area to produce these food crops. In the efforts to tackle this issue, numerous and different methods of crop production which include organic and inorganic / conventional cultivation, are now being used in the cultivation of these food crops and other farm produce. Organic production includes soil management of applying natural / organic fertilizer such as green or composted plant residues, animal and human feces, municipal sewage sludge and household waste as manures, crop rotation, intercropping, as well as any method that excludes the use of synthetic or chemical fertilizers and pesticides in crop production (Liu et al., 2013; Adamtey et al., 2016). Conversely, conventional crop production relies heavily on the use synthetic mineral

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fertilizers, pesticides, and genetic modification of crops in production. Over the years, organic production has witnessed exponential increase due to its environmental sustainability attributes and largely as a result of the growing perception that its products are healthier, safer, and nutritionally superior to their conventional counterparts. Whether this perspective holds true has become a matter of genuine and popular debate in recent times. Numerous studies have suggested that reduced and crude state of mineral contents in organic manures and prohibition of pesticides usage in organic production expose plants to biotic and abiotic stresses and vulnerability to pest attack (van Bueren et al., 2011; Ponti et al., 2012). Consequently, these plants responded by synthesizing more nutrients and other secondary metabolites to remedy the situation and this is what is later observed as higher nutritional content recorded for organic food crops (Atkinson and Urwin, 2012; Orsini et al., 2016).

However, it has been argued that there is not enough evidence to back up the claim that organic food crops are nutritionally superior, healthier, and safer than conventional ones, and that data in literatures are contradictory at best (Herencia et al., 2011; Hadayat et al., 2018; Szczech et al., 2018). Nevertheless, organic practice has continued to witness substantial growth in production but the indiscriminate use of all kinds of materials passed off as manure in organic soil management as a cost-effective source of nutrient has raised concerns for researchers about the safety of organic products. These concerns range from contaminations of produce by or from the applied manures which may result in serious health problems for consumers. It is believed that these materials passed off as organic manures by some farmers and growers in the cultivation of crops may contain different types of pollutants such as organic pollutants, high level of trace metals, and can serve as a reservoir for health relevant pathogenic bacteria, viruses, fungi, and parasites (Mugivhisa and Olowoyo, 2017; Allende et al., 2017; Alegbeleye et al., 2018). For instance, a quantitative microbial risk assessment to estimate the risk of diarrheal diseases from fresh produce consumption in India by Kundu et al. (2018) reported that the only cause of diarrhea was the exposure to foodborne pathogens like *E. coli* O157:H7 via consumption of raw fresh produce when estimating the annual risks of illness. Other pathogenic microbes include fungicidal microorganisms like *Penicillium*, *Alternaria*, *Aspergillus*, *Fusarium* and *Penicillium* species that most commonly infect grain crops and sometimes fruits and vegetables. These fungi species produce mycotoxins during both preharvest, and postharvest crop production and these mycotoxins constitute a major health risk to both humans and animal. Therefore, this review will evaluate the nutritional quality of organic and conventional food crops, and on the other hand, investigate evidence of trace metal and microbial contaminations in food crops.

Method

Search strategy and data extraction

A systematic search strategy tailored to some databases like ScienceDirect, PubMed, Scopus, Google Scholar, and Web of Science, was developed to identify relevant literatures for this review. All searches spanned slightly over a twenty-year period, from 2000 until 2022. The searches included original articles, review papers, as well as governmental published bulletin because of the non-commercial nature and greater authenticity of their reports. We conducted a broad search of literature with emphasis on keywords like microbiology quality assessment of farm produce, nutritional quality of organic and conventional food crops, toxic trace metal in food crops, mycotoxins in

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organic and conventional crops. The endnote X9 software was used in exporting these documents from the different databases to excel where the data were further cleaned by removing duplicates and non-English published articles.

Selection criteria

The selection criteria were based on Prisma framework of inclusion and exclusion method as described by Moher et al. (2009), with a slight modification (*Figure 1*). We mainly focused on mapping the existing literature on food crops. The subject area was then narrowed to the modes of cultivation of food crops, fruits, and vegetables. At this stage only 135 articles were included for screening after excluding 215 duplicates.

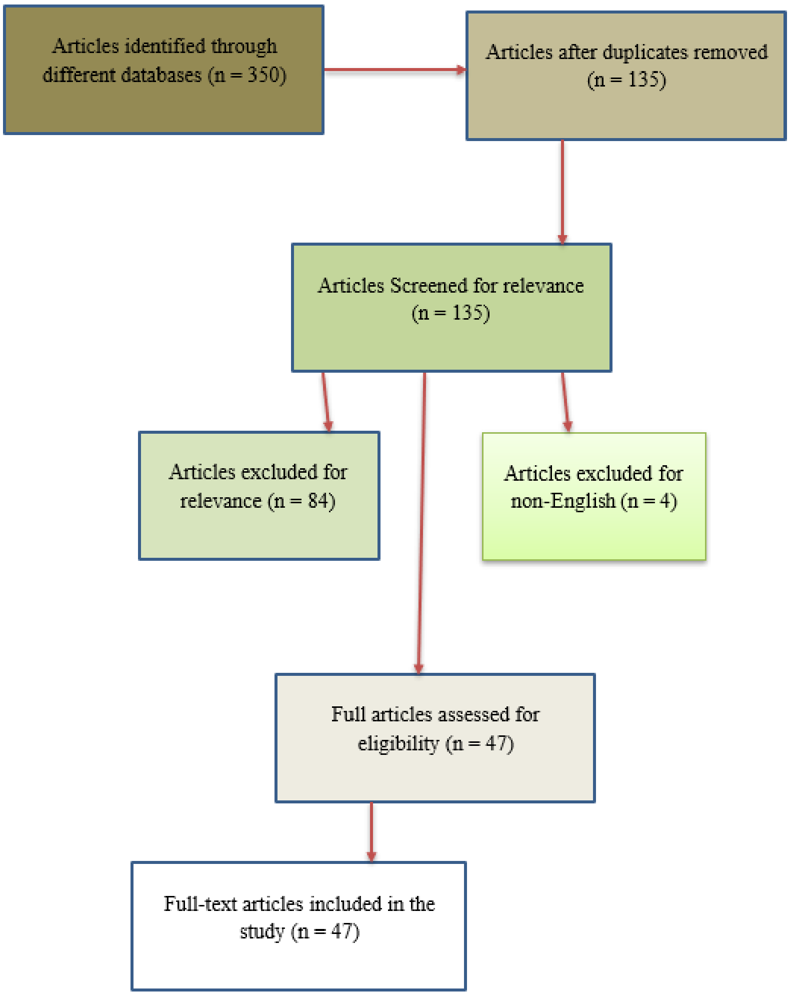

Figure 1. *Flow diagram illustrating the screening of materials for the review*

Quality assessment

In the quality assessment of this study, 84 articles were excluded after reading through the abstracts of the articles and checking the methodology to ensure quality and relevance of academic literature for inclusion in the review process. Only 47 Full text articles comprised of original research articles and review papers were eventually included in this study.

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Human health risk assessment from exposure to trace metals

The health risk assessments are set of methods used in evaluating the harmful level of trace metals in human. The risk to human health from the consumption of metal-contaminated food crops was characterized by the United States Environmental Protection Agency (USEPA, 2011), using the hazard quotient (HQ) and health risk index (HRI).

Results and discussion

Nutritional quality of organic food crops

This study reviewed scientific literature that compared nutritional quality of farm produce from two systems of production, otherwise known as organic and inorganic or conventional farming methods. Organic farming is characterized by the prohibition of the use of chemical synthetic fertilizers, pesticides, feed additives and genetically modified organisms and by the application of sustainable agricultural practices based on ecological principles and natural rules (Giampieri et al., 2022). The popular and continuously growing belief is that organic produce is nutritionally superior to their inorganic counterpart even though there is not enough evidence from literature to back this claim. Nevertheless, consumers are of the opinion that organic food crops have higher nutritional contents compared to the conventional produce. This review understands why this assumption has continued to grow. The agronomic method used in agriculture is said to affect the mineral uptake and metabolic processes in plants and invariably the quantity and the quality of the produce (Tetard-Jones et al., 2013; Mie et al., 2017). It is believed that organic management of plants exposes them to more biotic and abiotic stress such as reduced levels of nutrients in manures, vulnerability to pest attack, shortage of water and many more (van Bueren et al., 2011; Ponti et al., 2012). Consequently, in response to these stresses, organic plants activate series of defense mechanisms by synthesizing more nutrients and secondary metabolites which invariably leads to the observed differences in the nutritional values of farm produce (Atkinson and Urwin, 2012; Mickelbart et al., 2015; Orsini et al., 2016), and some studies have corroborated this theory. For instance, Reganold et al. (2010) reported higher levels of antioxidant activity, phenolics, ascorbic acid and anthocyanins in organic strawberries compared to conventional strawberries. Similarly, Mditshawa et al. (2017) in their review study of postharvest quality and composition of organically and conventionally produced fruit, reported that physicochemical and nutritional properties relating to the contents of vitamins, phenolics and antioxidants were higher in organically produced fruits.

Consequently, over the years, organically produced food crops have witnessed steady increase in demands due to the assumption that they are nutritionally superior to the conventional or inorganic produce among many other reasons (Tarozzi et al., 2006; Hunter et al., 2011; Mie et al., 2017). A study from the United States of America that investigated the attitude of consumers towards organic foods, reported that 84% of consumers are now favorably disposed to and prefer organic produce to conventional ones (Simonne et al., 2016). A considerable huge volume of research studies in this area have thrown up interesting findings, worth reviewing in order to establish few scientific facts. Numerous studies have reported contradictory results in their research where in one hand, some nutritional contents were higher in organic produce and some other nutrients were higher in conventional produce in the same study. For instance, one of our reviewed

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literatures (*Table 1*), Carodos et al. (2011), recorded higher ascorbic acid in organic acerola compared to the inorganic one, but in the same study, they also recorded higher ascorbic acid in inorganic strawberries compared to the organic ones. Similar results from Armesto et al. (2020); Maggio et al. (2013); Pedro et al. (2019); and Uckoo et al. (2015) in our reviewed articles corroborate the findings from Cardoso et al. (2011). These studies recorded higher levels of certain nutrients from organically cultivated crops and in the same studies conversely recorded higher levels of other nutritional contents for conventional crops. Furthermore, Herencia et al. (2011) recorded higher nutritional contents of macronutrients such as potassium and nitrate in conventionally cultivated crops compared to the organic ones, in their nine years of comparative study of nutritional quality of crops grown on organic and conventional fertilized soil. These studies contradict the assumption and belief that organic produce is nutritionally superior to their inorganic or conventional counterparts. A lot of studies have attributed the inconsistencies in nutritional differences in farm produce to several other factors like the species and variety of crops, and environmental factors, other than just method of the cultivation. Although there are already huge number of research works in this area, Mie et al. (2017) concluded that the nutrient composition differs only minimally between organic and conventional crops and that the available evidence does not constitute a sufficient basis for drawing conclusions.

Trace metals assessments of food crops

Table 2 shows the findings of previous studies on the evidence of trace metals in food crops. In the study by Jolly et al. (2013), the hazard quotient (HQ) values for Cd from *Amaranthus* was significantly higher than 1, a value considered unsafe in edible food. Hazard quotient is a proportion of the probable exposure to an element or chemical at such a level with no expected negative impacts when the quotient is less than one 1, but an indication of potential health risks resulting from an exposure, when it is greater 1 (Bermudez et al., 2011; Kacholi and Sahu, 2018). A similar study by Ugulu et al. (2021), recorded higher health risk index (HRI) values than recommended safe level of exposure for Cd, Co and Pb. Furthermore, our review also found that a study by Varol et al. (2022) recorded a Pb concentration in pepper that exceeded the maximum permissible concentrations, and a hazard index value greater than 1 for As, Co and Pb in tomato, which indicates a non-carcinogenic risk for consumers. Cadmium is a toxic trace element with no known biological purpose and has been linked with numerous diseases such as cancer, kidney problems and some other degenerative diseases (Sanchez-Chardi et al., 2007; Nnorom et al., 2020). Cobalt is an essential element that is beneficial to human as an integral component of vitamin B12 requires in sufficient amount in the production of red blood cells, and to prevent dermal hypersensitivity, and degeneration of the peripheral nervous system (Strachan, 2010). The toxicity effects and clinical consequences of Co include generation of reactive oxygen species (ROS), lipid peroxidation, alteration of calcium-iron homeostasis, and interruption of thyroid iodine uptake (Paustenbach et al., 2013) lead on the other hand, just like cadmium is a highly toxic trace element with no recognized biological purpose for organisms. The concentration of Pb has been substantially elevated due to anthropogenic activities such as vehicular emission, mining, and other industrial activities. Exposure to high concentration of Pb can cause short term illnesses such as vomiting, diarrhea, irritability, muscle, and joint pain, as well as long term illnesses like neurological, renal, endocrine, and reproductive disorder (Pandey et al., 2016; Silva et al., 2022).

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Table 1. *Comparative studies of nutritional quality of organic and conventional farm produce*

Titles	Nutritional contents	Results	Authors
Vitamin C and carotenoids in organic and conventional fruits grown in Brazil	Vitamin C Carotenoids	(Ascorbic Acerola) Organic > conventional (Ascorbic strawberries) organic < conventional	Cardoso et al. 2011.
Fruit and Soil Quality of Organic and Conventional Strawberry Agroecosystems	Antioxidant, Phenolics, Ascorbic acid, Anthocyanins	Organic > conventional	Reganold et al. 2010.
Comparison of nutritional quality of the crops grown in an organic conventional fertilized soil	Macronutrient concentration, and nutrient content	Nitrate content (organic < conventional)	Herencia et al. 2011.
Nutritional characterization of Butternut squash (*Cucurbita moschata* D.) Effect of variety (Ariel vs. Pluto) and farming type (conventional vs. organic)	Essential amino acids (EAA), Potassium (K), Magnesium (Mg), Sodium (Na), Manganese (Mn), folic acid (FA) and ß-carotene	EAA, K, Mg, Na, Mn (organic > conventional) FA and ß-carotene (organic < conventional)	Armesto et al. 2020.
Quality and nutritional value of vegetables from organic and conventional farming	Potassium (K), Antioxidant activity (AA)	K (Organic > conventional) AA (organic = conventional)	Maggio et al. 2013.
Organic vs conventional plant-based foods: A review	Physicochemical, nutritional and phytochemical quality	Contradictory results of nutritional quality from farming systems	Giampieri et al., 2022.
Physiological quality of organically grown vegetables	Sugar content, fruit firmness, dry matter, vitamins, and antioxidant	Biotic and abiotic stresses may influence nutritional contents	Orsini et al. 2016.
Qualitative and nutritional comparison of goji berry fruits produced in organic and conventional systems	Organic acids, ash, lipids, protein, carbohydrate	Proteins, total sugars, and total fibers (conventional > organic) Lipids and ash content (organic > conventional)	Pedro et al. 2019.
Phytochemical analysis of organic and conventionally cultivated Meyer lemons (*Citrus meyeri* Tan.) during refrigerated storage	Citric acid, amine, ascorbic, and phenolic	Phenolic, ascorbic (organic > conventional) Citric acid, amines (conventional > organic)	Uckoo et al. 2015.
Human health implications of organic food and organic agriculture: a comprehensive review	Vitamins, Nitrogen, Phosphorus cadmium, polyphenols, Fatty acids	Minimal nutrient differences between methods of production	Mie et al., 2017.
Effects of organic and conventional growth systems on the content of carotenoids in carrot roots, and on intake and plasma status of carotenoids in humans	Original	No differences	Soltoft et al., 2011.
Polyphenols and carotenoids in pickled bell pepper from organic and conventional production	Original	No difference in Lutein	Hallmann et al., 2019.
Effect of Organic and Conventional Management on Bio-Functional Quality of Thirteen Plum Cultivars (Prunus salicina Lindl.)	Original	Malic, Succinic and Shikimic acids were higher in organic	Cuevas et al., 2015.
The Effect of Cultivation Method of Strawberry (Fragaria x ananassa Duch.)	Original	Higer in organic	Drobek et al., 2020.

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Titles	Nutritional contents	Results	Authors
cv. Honeoye on Structure and Degradation Dynamics of Pectin during Cold Storage			
Vitamin C and carotenoids in organic and conventional fruits grown in Brazil	Original	Higher in conventional	Cardoso et al., 2011.
The impact of cultivation systems on the nutritional and phytochemical content, and microbiological contamination of highbush blueberry		Higher in conventional	Ochmian et al., 2020.
Carotenoids, tocopherols and ascorbic acid content in yellow passion fruit (Passiflora edulis) grown under different cultivation systems	Original	Higher in conventional	Pertuzatti et al., 2015.

Furthermore, Xu et al. (2013), recorded a value of 1.187 for total metal target hazard quotient for Cd, Cu, Pb, and Zn in their study that assessed the bioavailability of trace metals in garden soils and health risks via consumption of vegetables in the vicinity of mining area in Tongling, China. This also indicates a potential health risk of consuming vegetables from this area. Also, in our review, we found the study of Taiwo et al. (2022), very important. Their study which conducted contamination and human health risks assessments of metals in selected fruits in Nigeria, recorded a higher contamination risk values (ContR) than allowable limit of 1 for Cd and Cr (4.19 and 1.23) in banana, (4.08 and 1.16) in pineapple, respectively. The study also recorded contR for Cr (1.42) in walnut and values ranging from 1.71 to 19.0 for Pb in all the investigated fruits and vegetables. They established the possible development of cancer through the exposure to some of the metals in the fruits.

Furthermore, the study that investigated the hazard of selenium metal contamination in vegetables grown on soil amended with municipal solid wastes, found a corresponding increase of Se in the vegetable with increase in the concentration of applied municipal solid wastes (Ashfaq et al., 2022). Selenium is known as an essential trace element for humans, plant and animal in the right amount but as an environmental toxin in high dosage (Liu et al., 2021). The beneficial effects have been reported to include the promotion of growth and development in plant and human, production of enzymes, cofactors for metalloproteins, glucose and metabolic processes (Jung, 2008; Peralta-Videa et al., 2009; Iqbal et al., 2011; Alia et al., 2015) However in high concentration, the symptoms of Se poisoning have been reported to range from hair loss, fragile nails, liver damage, muscular spasms to arrhythmia and neurotoxicity (Thiry et al., 2012).

Also, in one of our reviewed articles, a study that assessed and compared trace metals in five most-consumed organic and conventional vegetables by Hadayat et al. (2018), found the mean concentrations of all the investigated trace metals to be lower than the acceptable limit by FAO/WHO. Nevertheless, they reported that the concentrations of Cd and Pb in conventional vegetables were higher than their organic counterparts. However, in the same study, it was stated that the mean concentration of Cu was particularly higher in organic lettuce and potato compared to the conventional ones.

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Table 2. *Evidence of trace metals in food crops*

Title	Type of research	Key findings	Authors
Transfer of metals from soil to vegetables and possible health risk assessment	Original	Cd (HQ =2.543) = unsafe Level	Jolly et al., 2013.
Contamination and health risk assessments of metals in selected fruits from Abeokuta, Southwestern Nigeria	Original	Contamination risk values for Cd, Cr, Ni and Pb of some of the fruits > allowable limits of 1 Possible development of cancer through exposure to some of the fruits	Taiwo et al., 2022.
Hazard of selenium metal contamination in vegetables grown in municipal solid waste amended soil	Original	↑ applied municipal solid waste = ↑ Se in both soil and vegetables	Ashfaq et al., 2022.
Assessment and source identification of trace metals in the soils of greenhouse vegetable production in Eastern China	Original	High concentrations of Cd and Hg in the garden soils for vegetable production	Yang et al., 2013.
Health risk assessment and multivariate apportionment of trace metals in wild leafy vegetables	Original	Health Risks Index (HRI) for Cr and Pb > 1	Abbasi et al., 2013.
Assessment of Trace metals bioavailability in garden soils and health risks via vegetable consumption around mining area in Tongling China	Original	The total metal (Cd, Cu, Pb and Zn) THQ = 1.1.87	Xu et al., 2013.
Arsenic and trace metal concentrations in different vegetable types and assessment of health risks from their consumption	Original	Pb > MPCs (maximum permissible concentrations) Tomato HI > 1	Varol et al., 2022.
Trace metal accumulation in pepper grown using organic fertilizers and health risk assessment from consumption	Original	Cd, Co, Pb (HRI >) = Potential health risks	Ugulu et al., 2021.
Assessment of trace metals in five most-consumed vegetables in the US: Conventional vs. organic	Original	Cd and Pb in organic vegetables < Cd and Pb in conventional vegetables	Hadayat et al., 2018.
Metals and micronutrients in some edible crops and their cultivation soils in eastern-central region of Tunisia: A comparison between organic and conventional farming	Original	Significant increase of toxic metal load in conventional food crops over organic food crops.	Hattab et al., 2019.
Nutritional quality and health risks of wheat grains from organic and conventional cropping systems	Original	Higher carcinogenic and non-carcinogenic risks of ingesting grains from organic cropping system	Zhang et al., 2020.
Heavy metals concentration in conventionally and organically grown vegetables	Original	Cd, Cr, Pb, and Zn were higher in conventional vegetables than the organic vegetables	Glodowska and Krawczyk, 2017.
The contents of selected metals in carrot cultivated using conventional, integrated and organic method	Original	Pb, Zn, Cd, and Cr were higher in conventional carrots than their organic counterpart	Gaweda et al. 2012.
A retail market study of organic and conventional potatoes (Solanum tuberosum): mineral	Original	Higher trace metals in organic potatoes than the conventional ones	Griffiths et al. 2012.

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Title	Type of research	Key findings	Authors
content and nutritional implications			
An elemental analysis of conventionally, organically and self-grown carrots	Original	No differences in the metals from the conventional and organic ones.	Krejeova et al. 2016.

Similarly, in another study that compared metals concentrations in organically and conventionally cultivated lettuce and strawberry, it was observed that Cd and Ni concentrations were higher in conventional lettuce but there was no significant difference in the concentrations of metals found in organic and conventional strawberries (Hattab et al., 2019). Concentration of metals in plants depends on several factors like soil pH and composition, metal permissibility, selectivity and absorption ability of the plant species and varieties, electrical conductivity, proximity of plants to polluted environment and some other environmental factors (Ahmad and Goni, 2010; Olowoyo et al., 2010; Ok et al., 2011; Aina et al., 2018). It is evident from literature there is presence of trace metals in food crops and farm produce irrespective of the systems of production.

Numerous studies have attributed these contradictory results to various factors responsible for the mobility and translocation of metals in plants.

Microbial assessment of food crops

Results of microbial assessments of food crops presented in *Table 3* showed that food crops can be contaminated by public health relevant pathogenic microorganisms. Allende et al. (2017) developed a microbial contamination model for quantifying *E. coli* in baby spinach during primary production. The model included contamination routes like soil and irrigated water, and potential impact of weather conditions and agricultural practices on *E. coli* levels present in the crop at harvest. The study concluded that growing periods (season) and agricultural practices (water quality and irrigation system) impacted the *E. coli* loads and prevalence in baby spinach at harvest. In a study that compared microbial quality of organic and conventional vegetables in Brazil by Maffei et al. (2013), they found *E. coli* in 41.5% and 40% of organic and conventional vegetables respectively. They also noticed that some organic vegetables recorded a higher count of this pathogen compared to their conventional counterparts. However, in a different study, a review of microbiology of organic and conventionally grown fresh produce by the same author in 2016, they concluded that although a number of studies have indicated that organic produce may pose a greater risk than conventional produce, however, from the result of their review, it appeared not to be a universal trend across studies. Fresh produce like leafy vegetables such as lettuce, spinach, cabbage, and root vegetables, like carrot, onions, potato, and beetroot can become easily contaminated by bacteria, fungi, virus, and other pathogenic organisms. There have been reports of contamination of farm produce by bacteria like *Salmonella species, Listeria monocytogenes* and *Escherichia coli* leading to high profile disease outbreaks (Mandrell, 2009; Berger et al., 2010; Tzschoppe et al., 2012; Yaron, 2014; Delbeke et al., 2015; Herman et al., 2015). For example, sprouted seeds were identified as the source of infection of Enterohemorrhagic *Escherichia coli* (EHEC) O104:H4 strain that caused high disease incidence in Germany in 2011 (Tzschoppe et al., 2012).

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Table 3. *Microbial and pathogenic quality assessment of food crops*

Title	Pathogens	Types of research	Authors
Quantitative contamination assessment of Escherichia coli in baby spinach primary production in Spain: Effects of weather conditions and agricultural practices	*Escherichia coli*	Original	Allende et al. 2017.
Microbial quality of organic and conventional vegetables in Brazil	Mesophilic aerobic bacteria, yeasts, molds, total coliforms, *Escherichia coli* and *Salmonella species*	Original	Maffei et al., 2013.
Microbiology of organic and conventionally grown fresh produce	*Salmonella spp, E. coli L. monocytogenes*, *B. cereus*, and *S. aureus*	Review	Maffei et al., 2016.
Occurrence of emerging foodborne pathogenic Arcobacter spp. isolated from pre-cut (ready-to-eat) vegetables.		Original	Mottola et al., 2016.
Assessment of pesticide residue and microbial contamination in raw leafy green vegetables marketed in Italy	*Salmonella species*, Enteropathogenic *Escherichia coli* (EPEC), Hepatitis E. virus (HEV)	Original	Santarelli et al., 2018.
Quantitative microbial risk assessment to estimate the risk of diarrhea diseases from fresh produce consumption in India	*Escherichia coli*, *Salmonella spp*	Original	Kundu et al., 2018.
Microbial quality of organic and conventional vegetables from Polish farm	*Escherichia coli*, aerobic mesophilic bacteria, yeasts, molds, and coliforms	Original	Szczech et al., 2018.
Sources and contamination routes of microbial pathogens to fresh produce during field cultivation	Pathogenic bacteria	Review	Alegbeleye et al. 2018.
A comparison of the nutritional value and food safety of organically and conventionally produced wheat flours	Mycotoxin	Original	Vrček et al. 2014.
Mycotoxins in organically versus conventionally produced cereal grains and some other crops in temperate regions	Mycotoxin	Review	Brodal et al. 2016.
Performance of Winter Wheat Cultivars Grown Organically and Conventionally with Focus on *Fusarium* Head Blight and *Fusarium* Trichothecene Toxins	*Fusarium* toxin	Original	Góral et al., 2019.
The influence of the fungal pathogen *Mycocentrospora acerina* on the proteome and polyacetylenes and 6-methoxymellein in organic and conventionally cultivated carrots (*Daucus carota*) during post-harvest storage	*Mycocentrospora acerina*	Original	Lourn et al., 2012.
Occurrence of *Fusarium* species and mycotoxins in Swiss oats—Impact of cropping factors	*Fusarium* head blight	Original	Schöneberg et al., 2018.
Fusarium mycotoxin content and Fusarium species presence in Czech organic and conventional wheat	Mycotoxin contaminants	Original	Polišenská et al., 2021.
Agronomic Factors Influencing the Scale of Fusarium Mycotoxin Contamination of Oats	Mycotoxin	Original	Kolawole et al., 2021.

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Pathogenic bacteria such as *E. coli and Salmonella spp*. are reported to have low prevalence in farm produce and thus serve as a good indicator for hygiene characterization (Holvoet et al., 2015; Delbek et al., 2015). For example, in the study of quantitative microbial risk assessment to estimate the risk of diarrhea diseases from fresh produce consumption in India, by Kundu et al. (2018), the result showed that universal fecal indicator was present in 40% of the investigated samples with their risk assessment model indicating the consumption of these raw vegetables was the only cause of diarrhea. Our study also found that the study that investigated the occurrence of emerging foodborne pathogenic *Arcobacter spp*. isolated from precut ready-to-eat vegetables by Mottola et al. (2016), reported a potential health risk associated with direct consumption of raw vegetables. The result of their study showed that *Arcobacter species* were detected in 27.5% of their samples. Additionally, our review also found that a study by Santarelli et al. (2018), which assessed the microbial contamination of raw leafy green vegetables marketed in Italy, reported that a small percentage (1%) of their vegetable samples were contaminated by *Salmonella spp*, Enteropathogenic *E. Coli* and Hepatitis *E. virus*.

Other health relevant contaminant in food crops includes mycotoxins such as deoxynivalenol (DON), zearalenone (ZEA), T-2 toxin, HT-2 toxin, nivalenol (NIV), ochratoxin (OTA) and patulin (PAT) which are produced by fungi species like *Aspergillum*, *Fusarium*, *Penicillium* and *Alternaria genera* and are prevalence in grain food crops, like wheat, oats, maize as well as fruits and vegetables (Brodal et al., 2016; Bernhoft et al., 2022). These mycotoxins if ingested in high concentration have been reported to cause serious health hazard and carcinogenic, reproductive, hepatotoxic, mutagenic, nephrotoxic, and teratogenic diseases (Sun et al., 2022). According to Kolawole et al. (2021), farming system is one of the major factors significantly influencing the prevalence and concentration of mycotoxins and that adherence to organic farming system was found to reduce contamination by type A trichothecenes. Similarly, Polisenska et al. (2021), recorded similar results and reported that organic farming system tends to reduce the occurrence of mycotoxin contamination in crops.

In contrast, Goral et al. (2019), recorded higher concentrations of *fusarium* kernel colonization in crop from organic system but found no difference in the *fusarium* head blight between organic and conventional systems. Few studies have suggested that other than farming systems, seasonal factors, geographical location, crop varieties, temperature are some other variables that influence the occurrence of these fungal contaminants in food crops (Brodal et al., 2016; Schoneberg et al., 2018).

Furthermore, the use of infection control chemicals like fungicides in conventional management would suggest a reduced fungal contamination incidence in conventionally produced food crops. However, studies have shown that not only is there are no current fungicides that can provide satisfactory prevention, but that there is a positive correlation between the occurrence and prevalence of fungal contamination of crops and the use of mineral nitrogen fertilizer which are commonly used in conventional production system (Fagard et al., 2014; Ferrigo et al., 2016; Sha et al., 2018).

The study by Szczech et al. (2018), compared the microbial quality of two systems of production vegetables from polish farm reported that vegetables from organic production recorded more bacteria counts and higher *E. coli* loads, yeast and molds compared to their conventional counterpart, and subsequently concluded that organic produce showed higher index of contamination. Although, opinions are still divided on which production methods harbors higher risks of contaminations, it has been reported that organic production has high potential of microbial contamination resulting from the application

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of amendments like composts, animal manures, green manures, and municipal wastes, because these materials support high biomass and regeneration of microorganisms and pathogens (Diez-Gonzalez and Mukherjee, 2009; Maffei et al., 2016). But consumers who through their concerns for environmental sustainability, and desire for quality farm produce that are also free from contaminations like pesticide residues, might have little or no knowledge of microbial and pathogenic quality of these products (Mukherjee, 2007; Denis et al., 2016).

Therefore, it is important, as suggested in one of our reviewed articles, a study by Alegbeleye et al. (2018), that all potential pathogen entry pathways in the food production chain that can predispose produce to microbial contamination, are established and continuously studied.

Conclusion

Although there is growing and general belief of nutritional superiority of food crops based on the method of cultivation, the nutritional variations and differences however have been inconsistent at best, but mostly insignificant. The general idea synthesized from numerous data from literatures suggest that there is insufficient evidence to draw a conclusive assertion of a particular system of production resulting in a significant nutritional superiority over the other. Furthermore, this study has evidently established the presence of trace metals in food crops and the concentration can reach a toxic level which can lead to potential health hazard. Finally, Pathogenic contamination of food crops is not a frequent occurrence but when it does happen, it is often with such devastating consequences. And this review observed that there is documented evidence of pathogenic contaminations in food crops irrespective of the systems of production. In the effort to reach the goal of providing sustainable food security, this study recommends adequate monitoring and quality control mechanism of the safety of food crops from unregulated farming practices, undocumented growers as well as subsistence farmers. This study is a preliminary framework of a more extensive ongoing study on a quality assessment of some selected vegetables cultivated under organic management.

Conflicts of interests. The author declares no conflict of interests.

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