

Food Safety, Nutritional and Economic Value of Organically and Conventionally Produced Foods

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Abstract

Around the globe, maintaining the food safety, nutritional value and food quality are the major challenges for the near future. Agriculture intensification and industrialized food production system are the major causes for contamination throughout the food chain and in water reservoirs by accumulating pesticide residues and reducing nutritional or sensory value of food product. It is important to assess the well-controlled studies to make a valid comparison between two major food production systems (organic and conventional) by comparing the nutritional value, safety and quality of food. Several reports indicating that vegetables and fruits produced by organic and conventional agriculture production systems may vary in sensory quality, nutrition value and amount of accumulated contaminants, although these findings are not consistent. Form several comparison studies between organic and conventional food grown systems, major findings are; organically produced plant products contain high dry matter, minerals (Mg, Fe) and more anti-oxidants; organic vegetables and fruits contain far less amount of nitrates. In future, the typical organic food distribution or post-harvesting management system should be evaluated to maintain the freshness, maturity and nutritional value of produced food.

Keywords: Food production systems; Macronutrients; Micronutrients; Minerals; Mycotoxins; Pathogenic microorganisms; Phytochemical contaminants

Introduction

During the twentieth century in developed countries, although level of mass foodstuff production was achieved, but the problems originated from intensive agriculture production system emphasized by researchers; ecologists, nutritionist, environmentalist, agronomists and physicians (Bonti-Ankomah and Yiridoe, 2006; Brandt *et al.*, 2011). Briefly, high energy and chemical (pesticides and fertilizers) inputs was the major causes for food chain contamination by accumulation of chemical residues, lowering food nutritional value and flavor contents (De Pascale *et al.*, 2016). In recent years, creating awareness among peoples regarding food security and safety, environment protection and human well-beings significantly increased public concerns, importance and demands for ecologically grown foodstuffs (Niggli *et al.*, 2007; Scialabba, 2007; Forman *et al.*, 2012). On the other hand in developing counties, researchers are also focusing on to find out the suitable ways to ensure the food security concerns. More emphasize is being put to safety, quality, nutritional value and health of staple foodstuff, almost one billion peoples are malnourished with no decreasing trend for the next couples of decades (FAO; WHO, 2004; Lester, 2006; WCRF, 2007; Forman *et al.*, 2012).

During the last few decades, several review studies have been carried to address the potential importance for human well-being and to investigate the nutritional and toxicological value of ecologically produced foodstuff, only a few numbers specifically considered and exhibited an alternative and sustainable food production system (Lairon *et al.*, 1982; Finesilver *et al.*, 1989b; Woese *et al.*, 1997; Bourn and Prescott, 2002; Magkos *et al.*, 2006; Brandt *et al.*, 2011). The conclusion derived from the previous studies may differ up to some extent, but these review studies exhibited the some beneficial aspects of organic food production systems. Organic food production and processing are wide ranging but overall this could be substitutive and helpful for the development of agricultural food production system that would be ecologically, environmentally, socially, economically and globally sustainable (Bourn and Prescott, 2002). The key principles and practices in an organic food production system are; lowers the use of synthetic chemicals both pesticides and fertilizers; to enhance the nutritional recycling within a farming system to increase soil fertility by encouraging the soil micro and macro-biota; sufficient amount and high quality food production and consider social and ethical importance of the food production and provisioning system (IFOAM, 2000; Mitchell *et al.*, 2007).

In this review, both organic and conventional food production system will be compared by comparing their nutritional value, safety issue and processing system. First of all, the nutritional value of organically and conventionally produced food stuffs will be described including amount of dry matter in various vegetables and fruits, vitamins, minerals and numerous macro-nutrients in a number of staple foodstuff and plant micro-constituents. Secondly, safety issues associated with organic and conventional food will be exhibited by comparing levels of contamination by phytochemicals, myco-toxins, nitrates and pathogenic micro-organisms. In third part, economic importance of organic and conventional foodstuffs by comparing consumer choice will be

reported.

1. Nutritional Value of Organic and Conventional Food

There are many factors has been evaluated in comparison studies between conventional and organic agricultural production systems i.e. agronomic factors, environmental factors, economical factors, soil physical characteristics (structure and texture) (Shepherd *et al.*, 2002; Mitchell *et al.*, 2007; Amedor *et al.*, 2015; De Pascale *et al.*, 2016), activity of soil micro-biota, farm biodiversity, pest and disease regulation (Niggli *et al.*, 2007), food product quality in terms of taste, nutritional value and shelf life, trade value of the products, farm management practices including farm nutrient and chemical inputs and political issues associated with both conventional vs organic food production systems (Knorr and Vogtmann, 1982; Finesilver *et al.*, 1989a; Lampkin *et al.*, 2000; Niggli *et al.*, 2007). Food quality in terms of food nutrition value, taste and shelf life is an era which has been caught much more attention and consideration in various comparison studies between organic and conventional food production systems (Knorr and Vogtmann, 1982; Boehncke, 1997; Forman *et al.*, 2012).

1.1. Dry matter

Most of dry matter content studies were carried out on numerous fruits and vegetables. Various types of organically produced root vegetables, tubers and leafy vegetables contained much higher dry matter contents as compared to conventionally produce vegetables (Wunderlich *et al.*, 2008; Hoefkens *et al.*, 2009), while no significant difference has been reported between conventionally and organically produced fruits and fruits vegetables (Bourn and Prescott, 2002; AFSSA, 2003; Guadagnin *et al.*, 2005; Amedor *et al.*, 2015).

1.2. Macronutrient (Starch, carbohydrates, proteins, lipids, fatty acids and fat)

Starch, carbohydrates, proteins, lipids, fatty acids and fat contents in foodstuff has been studied to compare the organic and conventional food production system (Amrein *et al.*, 2003). Studies regarding the difference in level of carbohydrates, starch and protein are too limited to make any conclusion between organic and conventional food production system (Puget *et al.*, 1998; Herencia *et al.*, 2011). It is reported that organic cereals, especially wheat crop, contain higher levels of protein as compared to conventionally grown (Schmidt *et al.*, 2005; Zörb *et al.*, 2006; Park *et al.*, 2015), but generally it showed lower protein levels in organic foodstuff as compared to conventional foodstuff (Woese *et al.*, 1997). Two comparison studies carried out cow's raw milk (Toledo *et al.*, 2002; Ghidini *et al.*, 2005; Croissant *et al.*, 2007) and on hen eggs (Kouba *et al.*, 2002) didn't show a significantly different levels of proteins. Few comparative studies have been carried out to compare the total lipid content in meat, pork, chicken and beef (Castellini *et al.*, 2002; Ghidini *et al.*, 2005; Angood *et al.*, 2008; Husak *et al.*, 2008). There was no significant difference found in pigs (Sundrum *et al.*, 2000; Millet *et al.*, 2004; Pietrosemoli *et al.*, 2016), but Hansson *et al.* (2000) reported that cows feeding on organic matter have more lean and bony meat as compared to conventionally-bred cows. More qualitative analysis showed that, cows and lamb feeding on concentrate grass led to 4X higher linolenic acid contents in muscles, an essential fatty acid of n-3 series, with associated decrease in the level of linoleic acid and oleic contents in muscle (Ghidini *et al.*, 2005; Ponnampalam *et al.*, 2015). Organically- grown cows and lamb meat have higher levels of polyunsaturated fatty acids in contrast with conventionally grown cows (Angood *et al.*, 2008; Samman *et al.*, 2008). Same strain of chicken raised under organic husbandry showed two-three fold lower abdominal fat in meat, two-three fold less fat contents in filet and 1.8 folds lower fat contents in leg meat (Castellini *et al.*, 2002; Husak *et al.*, 2008). Although, the levels of n-3 fatty acid in filet was considerably higher with no prominent difference in levels of saturated fatty acids. Total fat contents in milk didn't showed significant difference between organically and conventionally produce milk, while some studies exhibited higher polyunsaturated fatty acids levels in organically produce milk (Toledo *et al.*, 2002; Croissant *et al.*, 2007). Few studied revealed that organically produced virgin olive oil and edible oil has higher level of oleic acid as compared to conventionally produced oil (Gutiérrez *et al.*, 1999; Samman *et al.*, 2008).

1.3. Minerals

Key mineral elements generally reported in surplus amount in vegetables and fruits are phosphorus (P), calcium (Ca), iron (Fe), copper (Cu), zinc (Zn), iodine (I), magnesium (Mg), sodium (Na), potassium (K) and selenium (Se) (AFSSA, 2003). In fruits, a case study especially on apple, there were not so obvious regulation of mineral contents in varying fruit production system (Baert *et al.*, 2006). But for vegetables i.e. leek, turnip, potato, carrot, kale, onion, celeriac, lettuce and tomato and lettuce, higher levels of magnesium and iron was observed in organically produced vegetables with no other significant changes in level of other mineral elements (Zhao *et al.*, 2006). A long-term fertilization treatment study showed no significant effects on the mineral composition in cereals by difference with production system gradient (Wszelaki *et al.*, 2005). Alföldi *et al.* (1996) reported a significant higher level of Cu, Ca and Zn in organically produced barley as compared to conventional production system. A review study by Rembiałkowska (2007) reported that organically produced foodstuffs contain 29 %

more Mg and 21% more Fe as compared to conventional food production practices. For meat, Woese *et al.* (1997) also reported higher levels of iron and magnesium in meat from four comparative studies. However, chickens grown in open fields exhibited higher levels of iron as compared to chicken grown in housing conditions (Castellini *et al.*, 2002).

1.4. Vitamins

Many studies were carried out to investigate the mineral contents only in eggs and fruits and vegetables. Ascorbic acid (vitamin C) is the most studied vitamin among all hydrophilic vitamins, studies carried out on tomato-fruits (Caris-Veyrat *et al.*, 2004; Barrett *et al.*, 2007), potato-tubers (Hajšlová *et al.*, 2005), apple (Stracke *et al.*, 2009b) and kiwifruit (Amodio *et al.*, 2007) indicated higher level of ascorbic acid in organically produced food with conventional counterpart. For carotenoids and fat soluble vitamins, higher level of vitamin E was reported in organically produced olive oil (Gutiérrez *et al.*, 1999; Samman *et al.*, 2008). A review of 27 studies by Woese *et al.* (1997) reported difference in levels of β -carotene in organically and conventionally produced vegetables (Caris-Veyrat *et al.*, 2004). A positive correlation was observed between nitrogen fertilization and the levels of β -carotene in carrots (Stracke *et al.*, 2009a; Bach *et al.*, 2015). Ghidini *et al.* (2005) reported that cows fed by grass-rich pastures as compared to fed with silage, produce milk with higher levels of carotene and vitamin E.

1.5. Plant micro-constituents

There are a large number of micronutrients, plant secondary metabolites i.e. resveratrol, polyphenols and non-pro-vitamin carotenoids present in vegetables and fruits (Hajšlová *et al.*, 2005). Several factors involve to regulate these plant secondary metabolites levels in fruits and vegetables such as plant cultivar, maturity of food product, some abiotic factors (temperature and light) and production system (Rico *et al.*, 2007). Mostly studies reported significantly a higher levels of polyphenolic and phenolic compounds in organically produced foodstuffs i.e. pepper (Pérez-López *et al.*, 2007), apple fruit (Stracke *et al.*, 2009b), potatoes (Amrein *et al.*, 2003), orange (Lester *et al.*, 2007), pear and peach (Carbonaro *et al.*, 2002), tomato (Barrett *et al.*, 2007; Mitchell *et al.*, 2007) and olive oil (Gutiérrez *et al.*, 1999). Levite *et al.* (2000) reported higher level of resveratrol in organically produced wines. Rembiałkowska (2007) reported in his review study organically produce foodstuffs contains two fold the amount of polyphenol and phenols compounds as compared to conventionally produced food stuff. The level of salicylic acid in organic vegetable soups and tomatoes were considerably higher as compared to inorganic vegetables (Rossi *et al.*, 2008). While some anti-proliferative and anti-oxidants compounds present in organically produced foodstuffs showed positive effects on cancer cells but the mechanism of the impact of diets on chronic diseases still need to be fully investigated (Olsson *et al.*, 2006; Rossi *et al.*, 2008).

2. Conventional and Organic Produced Foods problems relating to Food safety

Scientific way for classifying well known threats and associated risks with reference to food safety is called risk evaluation. Main food contaminants are myco-toxins, agro-chemicals, worms, pathogens like bacteria, fungi and viruses, etc. (AFSSA, 2003; Forman *et al.*, 2012). Different researches focus various aspects of food safety relating threats, but less emphasis is given to viruses and worms. This article will enlighten applicable examples by reviewing previous and present studies.

2.1. Pathogens (microorganisms)

EU Scientific Committee (EU-SC) on Food raised voice about contaminating sources of food (vegetables and fruit) due to irrigation sources, animal feces and sewage sludge (SCF, 2002; Hoogenboom *et al.*, 2008). All these sources contain abundant pathogenic organisms that causing diseases in humans like pathogenic bacteria (Strauch, 1993), e.g., *Salmonella* sp. (Warnick *et al.*, 2001) and *Listeria monocytogenes* (Renterghem *et al.*, 1991). Utilization of sewage sludge and contaminated animal manures with chemical fertilizers are not permissible during organic farming system, composted manures with different phases of time. Aerobic composting procedure with high temperature has ability to kill or eliminate pathogenic microorganisms like *Escherichia coli* and *Salmonella enteritidis* (Tiquia *et al.*, 1998; Lung *et al.*, 2001). *Clostridium botulinum* is quite resistant to this composting procedure (Böhnel and Lube, 2000) and relatively exogenous bacteria swiftly eliminated under unsuitable conditions (Dowe *et al.*, 1997; Hoogenboom *et al.*, 2008). So, it is systematic procedure of aerobic composting for prevention of organic foodstuffs due to pathogens with improvement of organic fertilizer quality.

Under an examination during 1997-99 in France, milk samples were analyzed from different regions for microorganisms count under two husbandries (Echevarria, 2001; Hoogenboom *et al.*, 2008). It showed that limiting feeding by silage during organic husbandry is a way of contamination reduction in ruminants against *E. coli* and *Listeria monocytogene* (Herriott *et al.*, 1998). A Danish study showed that 36-49% contamination of

poultry samples with *Campylobacter* sp. observed under conventional poultry farms as compare to 100% samples in organic poultry farms (Heuer *et al.*, 2001; Castellini *et al.*, 2002). This comparative study is indicating lack of distinct source of organic foodstuff contamination as compare to conventionally produced food.

2.2. Mycotoxins

Mold growth on plants is the main source of mycotoxins (a big family of toxic substances). A vast variety of mold like *Aspergillus* spp., *Penicillium* spp. and *Fusarium* spp. are extensively toxic and heat-resistant and have ability to reach human beings through animals that feed infected or contaminated plants. Publically famous one health threatening toxins are Deoxynivalenol (DON), Patulin, Zearalenone (ZEN), aflatoxins, Fumonisin and Ochratoxin A (OTA), etc. and their notorious effects like liver cancerogenesis, teratogenesis, nephrotoxicity, immune-toxicity and embryo-toxicity. Their least limit is 0.1–2 ppb/kg with reference to body weight (Piemontese *et al.*, 2005; Baert *et al.*, 2006).

Organic foodstuff in Germany was contaminated with DON and a small amount by OTA under analysis of organic cereals samples (Birzele *et al.*, 2000), but that conventionally produced foodstuff samples were more contaminated. Under French investigation organic foodstuff is more affected with mycotoxins in few cases as compare to conventionally one (Malmauret *et al.*, 2002). Recent experiments showed that organically produced wheat has less ZEN and *Fusarium* contamination as compare to conventionally produce after pigs feeding (Schneweis *et al.*, 2005) and similar results were obtained after analyzing wheat flour for mycotoxin contamination (Zörb *et al.*, 2006). Aflatoxin contamination variations in milk samples has also been analyzed, in few studies high (Croissant *et al.*, 2007) and low level in organically produced milk (Ghidini *et al.*, 2005). Organically and conventionally produced cereals or foodstuffs are not creating a clear line or overall variations. It is only way to maintain least level of contamination and preventing deadlines under organic farming or agriculture, even the lack of utilization of chemical products.

2.3. Phyto-toxins

In organic agriculture, utilization of chemical products like herbicides, fungicides, insecticides and pesticides are not allowed that is brilliant protection measure for environmental biodiversity and living organisms (Hoefkens *et al.*, 2009). But environmental pollutants are still answerable contaminants for organic farming or organic foodstuffs. Many studies conducted for explaining and handling this source of contamination. An inspection in Sweden showed organically produced vegetables and strawberries did not show contamination, as 17–50% conventionally produced foodstuff contain (Bourn and Prescott, 2002). A Danish market analysis of organically produced vegetables and fruits showed only 2.8% samples contamination with chemical products, even all were below the 'Maximum Residue Limit' (Poulsen and Andersen, 2003) and undetectable chemical products contamination studied in Italy after analyzing 3500 samples of organically produced foodstuff (Tasiopoulou *et al.*, 2007).

A huge amount of foodstuff is contaminated by phyto-toxins. It was reported by the EU-DG-SANCO (2007) after scrutinizing 62,500 samples of foodstuff collected in EU-member states for inspection 706 kinds of chemicals. With the utilization of natural plant extracts against pest, weeds or herbs and disease control like pyrethrums, copper salts, sulfur and rotenone, in organic farming, is real advantage. These chemicals have ability to quickly degrade or evaporate from foodstuff making them contamination free foodstuff (Moore *et al.*, 2000).

2.4. Nitrates

In present situation with the intensive use of nitrogenous fertilizers or chemicals (Guadagnin *et al.*, 2005; Lairon, 2011), nitrates are becoming major health threatening causes due to their ability to form nitrites that have competing capacity with oxygen during blood circulation, binding ability with secondary amines to create anoxia and naturally cancer-promoting moieties way (Herencia *et al.*, 2011; Øvsthus *et al.*, 2015).

Vegetables provide 80% of nitrates as human diet. Fruits, legumes, cereals and animal products have very low level of nitrates (Guadagnin *et al.*, 2005), whereas processed meat contains more (Sebranek and Bacus, 2007). Analysis of five vegetables showed significantly lesser nitrate amount under organically grown salad, potato, turnip and leek, however not in kale (Lairon *et al.*, 1982; Lairon, 2011). Similar results obtained in Austria after analyzing 17 vegetables and in Germany an assessment on carrots with lesser nitrate amount in organically grown excluding in spinach (Niggli *et al.*, 2007; Bach *et al.*, 2015). The previous results indicated that variations in nitrates levels in vegetables are due to fluctuations in temperature, light intensity absorption or exposure, root nitrogen availability, cultivars specifications and species, like a small example, Chili sodium-nitrate stimulates nitrate accretion in subtle vegetables (Chassy *et al.*, 2006; Pérez-López *et al.*, 2007).

3. Economic Value and Consumers Preference of Organic Food

Arbenz *et al.* (2015) reported that there were 43.1 million of hectares under the organic during 2013. Regions with largest organic cultivated are Oceania (17.3 million hectares, 40% of world total organic cultivated area),

Europe 11.5 million hectares (27%), Latin America has 6.6 million hectares (15%), Asia 3.4 million hectares (8%), North-America 3 million hectares (7%) and Africa with 3.4 million hectares (3%). In 2013, there were about 2 million organic food producers, from total world organic producers 36% from Asia, Africa 29% and Europe contributes about 17%. About one fourth of total organic agricultural land and more than eighty percent (1.7 million) producers belong to developing countries (Arbenz *et al.*, 2015).

Likewise, during 2013, the global market sale value of organic commodities was \$72 billion, and revenue increased five times since 1999. Over past few years, the global sales of organic food products increased with an increasing rate. Both Europe and North-America produce over 90% of total global sales of organic products. Whereas, USA was the largest market for organic food products €24.3 billion (43% of global organic market), France with €4.4 billion (40%) and followed by China €2.4 billion. The largest per-capita consumption of organic food products was in Switzerland, Luxembourg and Denmark with more than €100 (Arbenz *et al.*, 2015).

Many studies were carried out to investigate the reasons behind the considerable increase in demands of organic food by consumers (Grunert, 2005; Hughner *et al.*, 2007). While numerous factors have relative importance to influence the choice of organic food vs conventional food products, but recent surveys reported that pesticide residues (Hoefkens *et al.*, 2009) in food items is the most important factor involve in the decision to purchase the organic foodstuffs as compared to the environmental hazard by pesticides (Grunert, 2005; Bonti-Ankomah and Yiridoe, 2006; Croissant *et al.*, 2007). However, environment protection is also the most important factor in several developed countries (Shafie and Rennie, 2012). Consumer from Germany more concerned with the environmental problems than UK's consumers. However this trend may be changing with recent investigations, because of approximately 70% organic consumers having good health just because of consuming organic foodstuffs (Woodward and Meier-Ploeger, 1999). Consumer prefers organic food on conventional food products considering following characteristics; benefits for human health and environmental safety, food freshness, nutritional value and food quality (Dorais *et al.*, 2008). Some organic food buyers at a co-operative considered protection of wildlife, pesticides free water supplies, protection of consumers from chemical residues in foodstuffs, importance of health and environmental factors are the most important factors for supporting organic food production system (Hoefkens *et al.*, 2009; Lee and Yun, 2015). Health was to be identified as an important motive for individual organic food buyers (Dorais *et al.*, 2008), whereas environmental issues are more important factors for wholesale buyers of organic food products (Forman *et al.*, 2012).

Consumers were found more reluctant to buy organically grown foodstuffs for following reason including; too expensive (Aryal *et al.*, 2009; Lee and Yun, 2015); poor market accessibility and availability of organic products, difficult to find retail outlets in supermarkets; unsatisfactory quality (appearance/flavor of organic food commodities) (Zhao *et al.*, 2007); satisfied with current conventionally grown food items (Lee and Yun, 2015); not familiar with organic term, legislation system and organic food logos (McEachern *et al.*, 2005; Napolitano *et al.*, 2010).

Conclusion

A number of plant compositional factors such as genetics, cultural practices, climate and post-harvest processing, influencing the investigations to carry out to compare the nutritional value of conventionally and organically grown food products. While, many studies were carried out all over the world to compare the differences in nutrition level in conventional and organic foodstuffs, but results varied from study to study with a significant variation to make a certain conclusion. An exception in nitrate contents tend to be higher in organic food products due to the more use of composts in organic production system as compared to conventional foodstuff. In past, most of studies only focused to a narrow range of nutrients, which are not sufficient to make clear indication of nutrition value level. Recent work has been carried out to investigate the impact of non-nutrient components and bioavailability of nutrients. These two areas of study will provide a great plank for future than simply examining the nutrients level trends.

Some studies exhibited the effects of conventional and organic feeding on the animal fertility, high level of sperm concentration has been reported in organic food consumers. These studies are confounded to only some factors or parameters and not enough to make some certain conclusive statements. Therefore, it would be worthwhile in near future, to undergo for further well-managed and well controlled studies to compare the definite impacts of organic and conventional food consumption. Furthermore, it would be more productive to compare food from certified organic food producers with same conventional food products by excluding the other factors such as distribution methods, processing, and type of foodstuff and storage duration.

A number of factors influence the organic food purchasing and consumer's perceptions and preferences such as product labeling (conventional and organic), age and awareness about organic farming. Previous studies on the pesticide residues didn't provide definite conclusions to effect the consumer decision for buying organic or conventional food products. However, the non-use of chemical inputs in a certified organic production system

as compared to use of chemical pesticides and fertilizers in conventional production system, may influence the consumer's purchasing decision for organic and conventional food products. Because many consumers choose organic food only because they assume that organically grown food have much lower amount of residue level.

Recently, the organic foodstuff contaminated with *E. coli* caused severe infection in some cases and stimulate health concerns, regarding the use of animal manures in certified organic productions system may cause some health problems in organic food consumers. In future studies, these health problems associated with organic food consumption need to be investigated. Organic production agencies should compost the animal manure prior to use, which may decrease the chances for contamination of organic food by pathogens. General cultural practices are also very important to minimize the risk of contamination of organic foodstuff by pathogens. This review mainly explored the three factors food safety concerns, nutritional and economic value to compare the organic and conventional production system. To evaluate a mark differences between these production systems, there is need to also consider some other aspects such as environment, political and social concerns related to organic and conventional food production systems.

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