Review

A Comprehensive Analysis of Organic Food: Evaluating Nutritional Value and Impact on Human Health

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A Comprehensive Analysis of Organic Food: Evaluating Nutritional Value and Impact on Human Health

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Abstract: In recent years, organic agriculture has gained more popularity, yet its approach to food production and its potential impact on consumers' health and various environmental aspects remain to be fully discovered. The goal of organic farming practices is to maintain soil health, sustain ecological systems, maintain fairness in its relationship with the environment and protect the environment in its entirety. Various health benefits have been associated with higher consumption of organic foods. This review identified some of these health benefits including a reduction in obesity and body mass index (BMI), improvements in blood nutrient composition as well as a reduction in maternal obesity and pregnancy-associated preeclampsia risk. Furthermore, organic food consumption can reduce the development of non-Hodgkin lymphoma and colorectal cancers. Upon reviewing existing literature regarding the nutritional value of organic foods, it was found that organic food contained higher levels of iron, magnesium, and vitamin C. However, the evidence available to draw definitive generalizations remains limited. In this review, we provided essential insights to support sustainable organic farming and highlighted the potential of organic food consumption that could play a pivotal role in positively impacting human health.

Keywords: organic foods; food safety; obesity; cancer; biodiversity; climate change; organic farming

1. Introduction

Organic farming aims to reduce environmental pollution and ensure animal welfare through protective farming management strategies that prevent exposure to harmful pesticides, industrial solvents, and synthetic chemicals [1][2]. However, this system of management goes beyond avoiding the use of synthetic inputs by basing its practices on four principles: health, ecology, fairness, and care [3][4]. The principle of health ensures that organic agriculture should sustain and strengthen the health of the soil, plants, animals, humans, and the earth as a whole [3]. The principle of ecology focuses on living ecological systems and how organic agriculture should work with, sustain, and emulate these systems [3][5]. The principle of fairness emphasizes the types of relationships that organic agriculture is built upon, as the types of relationships should ensure fairness with respect to the common environment and life opportunities [3]. Finally, the principle of care is based on the notion that organic agriculture should be managed in a safe and responsible way to protect and sustain the health and well-being of current generations, generations to come, and the environment [3]. To adhere to these principles, organic farming also includes practices such as crop rotation, intercropping, polyculture, covering crops, seeding timing, and mulching to name a few [3]. Overall, there has been an increasing awareness and demand for organic food among consumers in recent years due to its increased health-related benefits and its impact on increasing environmental biodiversity [6][7][8][9][10].

As stated previously, the major motivator in buying organic food is related to its health benefits, followed by the environmental and ecosystem impacts [11][12]. As a result, the worldwide organic

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food market is growing quickly, with an estimated growth rate of 10% since the year 2000 [13]. While there has been increased interest and awareness around the advantages that organic foods provide, there are various factors that affect consumers' attitudes towards organic food. The higher price of organic foods is one of the determining factors that influence the consumer's willingness to buy organic [11][14][15]. Another issue surrounding organic food is its limited distribution, thereby reducing accessibility for a broader population [11][15].

The purpose of this article is to express some of the important impacts of organic agriculture on human health and current trends in the market. Since food safety is the primary factor that affects consumer purchasing [16], our investigation delves into the impact of adopting organic farming practices to shed light on whether organic farming can actually yield favourable health outcomes for organic consumers. We examined the results of different studies conducted in the last 25 years to assess the potential impact of organic food consumption on human health. A combination of original studies and cohort studies from public literature was used to present our findings.

2. Organic versus Conventional Food

The process of producing organic food requires special considerations (Figure 1). In general, organic farming relies solely on biological and ecological processes, which aim to reduce the impact of agriculture on the environment and preserving the natural state of food [10][15]. The organic farming process also ensures that pest and disease control is achieved naturally without applying chemicals used in conventional farming [15][17]. Moreover, organic food should not be obtained from genetically modified organisms (GMOs) [15][18]. It is believed that organic farming improves soil fertility and promotes biodiversity. Studies have shown that local species richness and abundance can increase by ~34% and ~50% across various crops worldwide as compared to conventional farming practices [18]. Organic farming relies on mechanical weeding as an alternative to traditional herbicide input. This can result in increased weed cover, benefiting many organisms by promoting biodiversity [18]. The use of green manure, crop diversification, and small fields are also common principles in organic agriculture [18]. Consumers' interest in organic food has increased in recent years due to increased demand for natural products that are less processed and do not use synthetic and artificial fertilizers or pesticides in their production process [19][20].

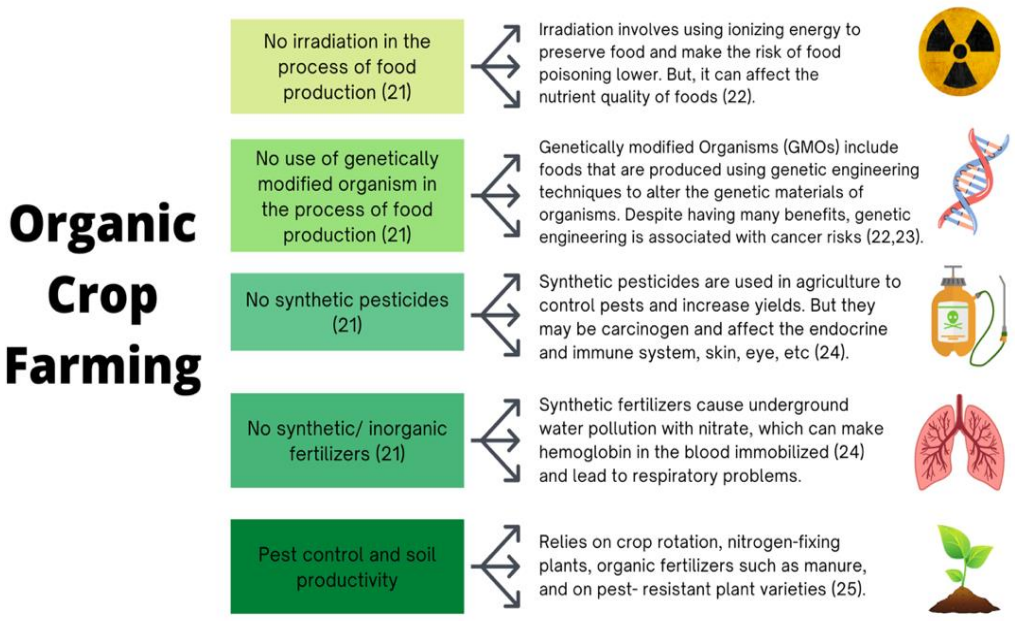

Figure 1. Organic crop farming at a glance [21][22][23][24][25].

Unlike conventional farming, organic farming does not use genetic engineering or synthetic pesticides in the food production process, so it is possible to assess the health effects of organic

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farming based on these principles. The use of genetic engineering and GMOs can result in various health risks, such as higher allergic reactions and unexpected interlinks between genes because of gene additions and modifications [22]. Glyphosate, a common ingredient of pesticides found in GM crops, has also been associated with cancer risks, especially non-Hodgkin lymphoma [22]. Glyphosate was first used as a broad-spectrum pesticide in 1974 [25]. As genetically engineered glyphosate-tolerant crops were introduced, glyphosate quickly spread worldwide and has now become the most widely used pesticide in agricultural and residential sectors [25]. An Agricultural Health Study (AHS), which assessed the health outcomes of licensed pesticide applicators in North Carolina and Iowa, evaluated the effect of glyphosate on the development of tumours [25]. In their study, 82.8% of 54251 applicators used glyphosate, but there was no statistically significant link between glyphosate and tumour growth [25]. In spite of this, they found that in individuals belonging to the highest exposure quartile, the risk of acute myeloid leukemia (AML) was increased, but not statistically significant [25]. Glyphosate is also an organophosphorus compound which interferes with aromatic amino acids' synthesis through a mechanism unique to plants [26]. However, concerns have arisen about glyphosate's potential genotoxicity through the induction of oxidative stress for human cells in vitro and in animal experiments [25]. As a result, pesticide use may adversely affect human cells through mechanisms still unclear.

Furthermore, pesticides used in agriculture can accumulate in soil and water, where they can quickly enter the food chain and affect human health [22]. The health effects can range from allergic reactions to lung damage causing breathing difficulties, nervous system problems, birth defects, and the risk of chronic diseases such as cancer [22]. Dichlorodiphenyltrichloroethane (DDT), classified as an organochlorine insecticide (OCI), functions by opening sodium channels in the human nervous system. This causes an increased firing of action potentials which can lead to spasms and, in severe cases, eventually death [26][27]. The carbamate insecticides inhibit the acetylcholinesterase enzyme, interfering with the termination of signals with Neary receptors in the nervous system [26]. Acetylcholinesterase breaks down acetyle choline in the synapse, which results in neuronal transmission being terminated [26]. The growth regulator herbicide 2,4-D, which kills plants such as weeds, has been shown to cause severe eye irritations and fertility problems in men [26]. Additionally, a number of studies have also linked anilide/aniline herbicides to colon and rectal cancer risks [26]. Thus, it may be possible to minimize these health risks by re-orienting agricultural practices toward more organic approaches.

Nutritional Benefits

The nutrient content of crops is affected by various factors, some of which have the same influence on both organic and conventional agriculture systems while others exert a more significant impact on one agricultural practice over the other [15]. Studies comparing the nutrient content between organic and conventional crops have revealed inconsistent results. Further on, many of these studies lack the necessary control factors to validate the results, such as failing to consider the different environmental and growing conditions that affect crop quality [15]. In 2012, Smith-Spangler et al [21] reviewed the results of 223 studies examining the nutrient content of organic foods, including ascorbic acid, phosphorus, calcium, magnesium, iron, and various vitamins. The findings showed that organic fruits, vegetables, and grains do not exhibit significantly higher nutrient levels compared with their non-organic counterparts. However, organic produce did show higher levels of phosphorus when compared with non-organic produce [21]. All in all, the evidence was not strong enough to suggest that organic foods are more nutritious than non-organic foods. However, further recent experiments have demonstrated that some organic foods, such as corn grain, wheat flour, broccoli, tomato, back sesame and leafy vegetables, contain more minerals and vitamins, which are discussed below.

Mineral Content:

The most essential minerals are calcium (Ca), magnesium (Mg), potassium (K), iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), selenium (Se), and iodine (I). Studies have shown that the mineral content of fruits does not differ significantly between organically grown and conventional

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methods [28][29]. Studies on organic vegetables, however, revealed a higher level of iron and magnesium compared to conventionally grown vegetables. Overall, results on the amount of iron and magnesium content in organic crops were higher by 21% and 29%, respectively [28]. This finding was further compounded by Rembialkowska, where the results of many experiments demonstrated a higher level of iron, phosphorous, and magnesium in organically grown compared to non-organically grown products (Table 1) [30].

Vitamin Content:

Experiments on the various vitamin contents of different vegetables and fruits are limited. Many experiments were conducted comparing the Vitamin C (ascorbic acid), E, and A levels of organic foods versus non-organic products. The results showed higher content of Vitamin C in organic potatoes, tomatoes, kale, and celeriac as well as higher Vitamin E content in organic olive oil [28]. Worthington's experiment revealed 27% higher Vitamin C levels in organically grown foods [31]. Some studies on beta-carotene (Vitamin A precursor) have shown that the beta-carotene content of organic foods greatly depends on the type of fertilizer used, and N-fertilizers have been shown to yield a higher level of beta-carotene in carrots [28][29]. Other experiments have shown similar outcomes in conventional agriculture, such that increased fertilization changes the content of secondary plant metabolites [32]. It was revealed by Mozafar [33] that nitrogen fertilizer used in conventional fruits and vegetables could increase the amount of beta-carotene and reduce vitamin C levels. Moreover, a study by Yu et al [34] on organic and conventionally grown summer corn revealed that the levels of phosphorus, magnesium and potassium in organic corn were 30%, 20% and 30% higher than in conventional corn, respectively, and this difference was significant. They also found higher levels of zinc and iron in organic corn, but this increase was not significant [34].

Other Compounds:

Oxidation of phenolic compounds by the polyphenol oxidase (PPO) enzyme is part of the plant antioxidant defence mechanism (to repair injuries on their surface). Phenolic compounds act as a chemical barrier against invading pathogens. Intact antioxidant defence in plants has been shown to have important implications for human health, including playing an anticarcinogenic role [30]. Organic cultivation operations have been revealed to increase the polyphenol content of peaches and pears as compared with their conventional counterparts [9]. Moreover, increased activity of the PPO enzyme towards chlorogenic and caffeic acids (antioxidant agents) was observed to be notably higher in the organic samples of peaches and pears [9]. Overall, various studies on organic crops have observed between 18% and 69% increased antioxidant activity in these products [35]. Intake of antioxidants and phenolic compounds from food consumption is important because these compounds have been shown to effectively reduce the risk of chronic diseases, including some neurodegenerative, cardiovascular and cancer [35].

Another organic compound that has increased in quantities within organic foods is salicylic acid. Salicylic acid is a metabolic component of aspirin and has a high anti-inflammation capacity [36], and its intake from dietary sources has beneficial health effects. Aspirin and its metabolites, including salicylic acid, can reduce the risk of cardiovascular diseases and reduce up to 40% of the risk of colorectal cancers [37]. Relevantly, organic practices have been shown to increase the salicylic acid content of vegetable soups in comparison to their conventional counterparts [36].

Overall, several studies have demonstrated that there is an increase in iron, magnesium, Vitamin C, Vitamin E, Beta-carotene, polyphenol content, and salicylic acid in select organic foods.

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Table 1. Nutritional quality comparison of organic crops versus conventional crops [30]. Given the remarkable increase in organic farming in recent years, and especially in Canada, we expect more research to be done on the nutritional content of organic food and recommend that these assessments be food-based so that the nutritional content of each organic food will be examined separately to make a more comprehensive assessment of the quality of each organic food.

Component	Mean % difference	Range (%)	Number of studies
Vitamin C	+28.7	−38 to +135.5	21
Phenolic compounds	+119.3	−56.6 to +734.2	15
Iron	+21.1	−73 to +240	16
Magnesium	+29.3	−35 to +1206	17
Phosphorus	+13.6	−44 to +240	18

3. Impact on Human Health

The findings of clinical experiments evaluating the health effects of organic food on humans are limited compared to other nutritional epidemiological studies, as these studies are mostly short-term or confounded by differences in dietary patterns and lifestyles that profoundly affect human health [38]. For example, some observational studies do not examine the influence of other health factors that differ between organic and non-organic food consumers [38][39]. However, the compounds in organic fruits and vegetables are generally thought to promote human health and longevity [40]. Thus, consumers who consistently eat organic food tend to choose more fruits and vegetables and less meat, which could lower the incidence of mortality and chronic disease [40][41][42][43][44][45]. Moreover, research has shown that people who usually choose organic food are female, possess higher education and income status, and have a healthier lifestyle by smoking less and being more physically active [39][41][46][47]. As a result, the diets of organic and non-organic consumers may be compositionally different. The purpose of this section is to provide evidence from studies that have evaluated the effect of organic food on human health outcomes.

4. Epidemiological Findings Related to Human Health

BMI and Obesity:

Body mass index (BMI) is a weight-to-height index that divides an individual's weight (kg) by their height (m^2). It can be used as an indicator to determine obesity and overweight in adults [48] . The World Health Organization (WHO) defines obesity as a BMI equal to or greater than 30 in adults and overweight as a BMI equal to or greater than 25 in adults [49]. The result of a large prospective experiment on the consumption frequency of organic foods and corresponding change in BMI over time has shown a 37% lower risk for both overweight and obesity after regularly eating organic for 3.1 years. Changes in BMI were also negatively associated with the consumption of organic food [50]. Moreover, the results have illustrated a better outcome regarding overweight and obesity when the participants consumed organic food regularly compared to those who consumed irregularly or non-consumers. Particularly, males who regularly consumed organic foods, compared with non-regular consumers, showed a 36% and 62% lower probability of overweight and obesity, respectively, and females who regularly consumed organic foods showed a 42% and 48% lower probability compared with non-consumers [50]. Overall, their results illustrated a strong reduction in the risk of overweight and obesity among high-frequency organic food consumers [50]. Another cross-sectional study by Perez-Cueto et al. was conducted to compare food-related lifestyles (FRLs) between 2437 obese and non-obese respondents in five European countries (Belgium, Denmark, Germany, Greece and Poland) [51]. According to their experiment, obese participants scored lower on most dimensions of FRL related to food quality, particularly organic products, suggesting that eating more organic products reduces obesity risk.

Furthermore, a cross-sectional study [52] in France comprised of 5855 participants, including children, adolescents, and adults, assessed the relationship between organic food consumption and obesity over a one-year period. The results showed that in all age groups, higher consumption

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frequency of organic food was associated with lower BMI and obesity – however, the strength of this relationship was reported to be small [52]. An additional study examined the association between organic food consumption and obesity risk among 37,706 Sister study participants between 2003 and 2009 [53]. The participants in the age range of 35-74 reported eating organic food (including meat, dairy, and produce) never, less than half of the time, about half of the time, or more than half of the time in the past 12 months. The organic diet score (ODS) was calculated based on the frequency of organic food consumption, with a higher score indicating more frequent consumption. The researchers compared BMI at the time of enrollment and over a mean 8.3-year follow-up and found that women who ate organic foods not only had lower baseline BMI, but also that eating less organic foods was inversely related to weight gain [53]. Overall, these studies have demonstrated the association between organic food consumption and reduced risk of obesity.

Blood composition:

Clinical studies have demonstrated that individuals who consume a high amount of organic food exhibit more favourable blood compositions comapred to those who consume low amounts of organic food. Notably, organophosphrous pesticides (OPs) diethyl-thiophosphates, dimethylthiophosphase, dialkylphosphates and free 3-phenoxybenzoic acid showed significant reduction in urinary concentrations for frequent organic food consumers [39]. Previous studies have shown an association in OPs and hormone concentrations, particularly hormones involved in reproduction. [54]

Moreover, the clinical studies results revealed higher nutritional content in fasting blood plasma samples of frequent organic food consumers [39]. Plasma levels of magnesium, fat-soluble micronutrients (a-carotene, b-carotene, lutein, and zeaxanthin), fatty acids (linoleic, palmitoleic, g-linoleic, and docosapentaenoic acids) and some fatty acid desaturase indexes, were found in greater concentrations in frequent organic food consumers [39]. Another study found that individuals who consumed mainly organic food exhibited higher antioxidant capacity in their blood [55]. Pregnant women who consumed over 90% organic meat and dairy products in their diets showed elevated levels of anti-inflammatory and growth-stimulating fatty acids in their breast milk [55]. While some studies were able to conclude that organic food enhances animal physiology, including immunity and hormonal balance, the direct impact on humans remains inconclusive due to the lack of data available [55].

Impact on Children's Health:

One of the main draws of the organic diet is that it claims to limit pesticide exposure, which is associated with damaging genotoxic effects including cancer-causing carcinogens and disruptions in the endocrine and nervous systems of the body [56]. Indeed, the cluster-randomized crossover trial done by Makris et al. (2019) demonstrated that pyrethroid and neonicotinoid pesticide metabolite concentrations were significantly lower in Cypriot children following a 40-day organic diet [57]. Importantly, this outcome was linked to a reduction in various biomarkers of oxidative stress and inflammation [57], suggesting a potential mechanism by which organic foods confer health benefits to the consumer. Other studies [57][58] examining the effects of dietary pesticide exposure have also found similar results, and seemingly agree that following an organic diet protects against dangerous pesticide metabolite concentrations in the body. Considering prenatal exposure to pyrethroid pesticides was linked to poorer neurological and cognitive outcomes in children [58], eating organic may play a neuroprotective role and lead to better developmental outcomes. While other studies have criticized that this claim remains unsubstantiated due to confounding factors such as differences between growing conditions and lifestyle factors, the benefits of the organic diet seem to be reflected in positive health outcomes of study participants and is a promising avenue of research.

Health Effects Associated with Pesticides

Pregnancy-Related Health Characteristics:

Nutrition during pregnancy has critical effects on maternal and fetal health. Simões-Wüst et al [59] assessed the association between organic food consumption and pre-pregnancy health characteristics. This study has shown that mothers who consumed organic food had better health

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outcomes such as a lower risk of overweight and obesity, a more favourable BMI before pregnancy, and a lower prevalence of pregnancy-associated diabetes [59]. Furthermore, the results of this study have indicated a lower incidence of hypertension among participants who consumed organic food compared with non-organic consumers [59]. However, the association between blood pressure and organic consumption did not seem to be linear. Analysis of blood lipids also revealed higher levels of LDL among organic consumers, and the result was statistically significant [59].

Another study compared male newborns of female organic consumers to female non-organic consumers in relation to hypospadias and cryptorchidism [60]. It has been thought that maternal diet and environmental contaminants could affect the risk of these birth defects through placenta or hormonal disturbances. The study found that there was no meaningful association between cryptorchidism and organic consumption. However, it was found that there was a lower prevalence of hypospadias among males whose mothers consumed organic foods during pregnancy [60]. It should be noted that the study's parameters around the "organic consumer" were individuals who indicated that they either sometimes, often, or mostly consumed organic foods in one of six categories (vegetables, fruit, bread/cereal, milk/dairy products, eggs, and meat) [60].

Consumption of fruits and vegetables with high pesticide residues has shown lower success rates for achieving clinical pregnancy among women going through infertility treatments [61]. A study done by Chiu et al [61] discovered that women who consumed more than 2.3 servings per day of such foods had 18% and 26% lower chances of achieving clinical pregnancy and live birth, respectively. This was not significant amongst women who consumed fruits and vegetables with low pesticide residues [61].

Consumption of organic foods has other maternal and fetal health benefits due to reduced exposure to pesticide chemicals. A study on the consumption frequency of organic vegetables in mid-pregnancy among Norwegian mothers has demonstrated that higher consumption of organic foods is associated with reducing the chance of developing pre-eclampsia [62]. Pre-eclampsia is present among 5-8% of pregnant women, which can induce maternal and fetal mortality, cause an exaggerated inflammatory response of the immune system, and pregnancy-associated hypertension [63]. Three factors might explain this reduced risk, the first being reduced exposure to organophosphorus pesticides, particularly Chlorpyrifos (CPF) [62]. CPF has the ability to increase the permeability of intestinal cells in the gut and thereby induce inflammation [62]. The reduced inflammatory response may also be due to the ingestion of plant secondary metabolites with anti-inflammatory properties, including salicylic acid and polyphenols. A third explanation could be that eating organic vegetables improves the intestinal microbiota which results in an anti-inflammatory response, thereby reducing the likelihood of preeclampsia occurring [62].

Overall, there have been several studies that have demonstrated benefits to organic foods either in relation to consumption or the lack of exposure to pesticide chemicals. However, further studies would have to be done surrounding this topic to demonstrate a more comprehensive finding.

Risk of Cancers:

In a 9.3-year follow-up study [64], the association of organic consumption frequency and cancer incidence was assessed among 623 080 middle-aged women in the United Kingdom. Although previous studies have shown a lower risk of breast and soft tissue cancer among organic consumers, this prospective study revealed no such relationship. However, there was some evidence that demonstrated that the risk of non-Hodgkin lymphoma (NHL) was reduced by 21% in women who reported usually or always consuming organic food [64].

Another study [65] was designed to assess the overall change in cancer incidence and consumption frequency of organic foods. This study revealed that those who consumed organic foods showed a lower risk of NHL (21%, which was similar to the result of a previous study among UK women [64]) and lower risk of postmenopausal breast cancer among participants who consumed organic food frequently (in contrast with the previous study among UK women which found no reduction in breast cancer risk) [64][65]. According to this paper, the negative association between organic food consumption and cancer risk was possibly due to lower exposure to synthetic pesticides in organic farming. Specifically, exposure to certain chemicals, such as malathion, terbufos, and

diazinon has been associated with a 22% higher risk for NHL [65]. The same reasoning can be used to explain the reduced risk of breast cancer; lower exposure to synthetic chemicals can lead to a lower risk for breast cancer among high organic food consumers [65].

Exposure to chemical pesticides is also associated with an increased risk of different types of cancers. In South Spain, a study [66] on the population of 10 districts, which were categorized based on the potential environmental exposure to pesticides, showed an increased rate of stomach, colorectal, liver, skin, bladder, and brain cancer for regions with a higher level of pesticide exposure. In addition, there was an increased rate of prostate, testicular, and lung cancer among male residents in areas where the level of pesticide exposure was high [66]. Many experiments were conducted on the potential carcinogenicity of pesticides using animal models, and these studies have confirmed that the potency of the pesticides and the level of exposure should be considered as factors that increase the risk of cancer development [67]. In animal studies, the carcinogenic potential of some pesticides such as organochlorines, creosote, and sulfallate has been observed. Notably, arsenic compounds and insecticides are considered as human carcinogens by the International Agency for Research on Cancer [66]. Together, these studies suggest that exposure to pesticide chemicals, which are extensively used in conventionally grown products, potentiates cancer risk. Thus, eating more organic foods could help reduce exposure to these pesticides and consequently, potentially also reduce the risk of dangerous human diseases.

5. Concluding Remarks

Evidence in current literature suggests that the consumption of organic food confers promising health advantages for various consumer groups. However, due to confounding factors such as lifestyle differences and study duration, the evidence provided is insufficient to establish these dietary benefits. Nonetheless, it is important to acknowledge that organic food consumption was linked to reductions in BMI and enhancements in blood nutritional composition among males, females, and children, although these blood nutritional improvements have not been directly linked to specific physical health benefits. Further on, organic food has been increasingly popular amongst women due to the claim that they are pesticide-free, and pesticides have been associated with adverse effects on reproductive and immune health. Thus, while research on the health benefits of organic food consumption is promising, further comprehensive and longer-term studies are required to provide a clearer and concrete understanding of its overall health impacts.

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