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Review

Food quality assessment in organic vs. conventional agricultural produce: Findings and issues

Tiziano Gomiero[a,b,*]

[a] Independent scholar, Mogliano Veneto, Treviso, Italy
[b] Fellow Department of Environmental Studies, Faculty of Social Studies, Masaryk University, Brno, 602 00, Czech Republic

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ABSTRACT

Organic food is increasingly attracting the interest of consumers, as it is perceived to be healthier than food produced by conventional agriculture, and to be more sustainable for the environment. This paper provides a review on the quality of organic produce in terms of its nutritional value, the presence of pesticide residues, heavy metals, mycotoxins and bacterial contamination, and the issue of antibiotics. The use of Recombinant Bovine Growth Hormone is addressed. Hydroponic techniques are also discussed. Compared to conventional produce, organic produce is richer in some useful compounds. Nevertheless, heterogeneous findings have been reported. Studies concord in finding organic food much less contaminated by pesticides, and with residues of much lower toxicity compared to those found in conventional foods. As for heavy metals, mycotoxins and bacterial contamination, there are no significant differences in organic produce compared to conventional produce (with the exception of Cd, found to be lower in organic produce, which is a positive finding). More effective and detailed guidelines should be devised for the design and reporting of both primary studies and meta-analyses. Pesticide residues should be assessed both quantitatively and qualitatively. The issue of multiple residues should also be addressed. Of course, organic produce cannot be assumed, a priori, to be safe. Sound monitoring needs to be constantly performed. It is concluded that organic agriculture can provide important benefits to human health and to the environment, and promote a more compassionate treatment of animals. It is hoped that agricultural policies will pay more attention to organic, agroecological and low-input agricultural practices, and invest in research and innovation.

1. Introduction

Organic food is increasingly attracting the interest of consumers, as it is perceived to be healthier than the food produced by conventional agriculture, and more sustainable for the environment (Hughner et al., 2007; Canavari and Olson, 2007; Stolz et al., 2011; Carlson and Jaenicke, 2016; Mie et al., 2016; EC, 2017). Organic products, once available only in a few specialised shops, are now widely available in most supermarkets, and a large percentage of consumers are aware of them. According to IFOAM (2016), in 2014, on a global level, organic agriculture was practiced in 172 countries, on a total of about 44 million hectares (1% of agricultural land), and the size of the organic market reached 80 billion USD. Over the last decade, demand for organic products has steadily increased (notwithstanding the recent economic crisis). In Europe and North America, the organic market is experiencing a rapid expansion: in recent years, it has reached a growth rate of 10–15% per year (EC, 2014; IFOAM, 2016; Carlson and Jaenicke, 2016). In some European countries (*i.e.*, Denmark, Switzerland and Austria) organic food now represents 6–7% of the market, quite a significant percentage (IFOAM, 2016; EC, 2014). It is also forecasted that the market for organic produce will continue to grow (IFOAM, 2016; Carlson and Jaenicke, 2016).

Expansion of the organic market has been welcomed by many as a sustainable agricultural alternative (i.e., reducing the use of agrochemicals, improving soil conservation), while others point out that organic agriculture is less productive, and that it may lead to an increase in food cost and in the demand for land (Gomiero et al., 2011a; Seufert et al., 2012; Tuomisto et al., 2012; Reganold and Wachter, 2016).

In this paper, I provide a review on the quality of organic food in terms of its nutritional value, using a number of criteria. The paper is organised as follow: in Section (2), I introduce the principles of organic agriculture and some contentious issues concerning productivity and environmental impact, and then discuss the reasons leading consumers to buy organic food. In Section (3), I review the main findings concerning the nutritional value of organic products. In Section (4), I

* Corresponding author at: Mogliano Veneto, Via Cortellazz0, 31021 Mogliano Veneto, Treviso, Italy.
E-mail address: tiziano.gomiero@libero.it.

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discuss pesticide residues found in food, in qualitative and quantitative terms. In section (5), I report information concerning heavy metals, mycotoxins and bacterial contamination. In Section (6), I discuss the use of antibiotics in livestock and its possible effect on human health. In Section (7), I deal with the use of Recombinant Bovine Growth (rBGH). In Section (8), I provide a brief overview of hydroponics. In Section (9), I discuss the main findings. In Section (10), I draw some conclusions and make some recommendations.

2. Organic agriculture: what it is and why consumers buy organic food

In this section, the principles of organic agriculture are briefly introduced and some issues concerning productivity and environmental impact are discussed. As the market for organic food is growing fast, it is important to understand what moves consumers to buy organic products. A review of the literature on the topic is summarised.

2.1. Organic agriculture: a brief introduction

Organic agriculture refers to farming practices regulated by international and national institutional bodies, which certify organic products from production to handling and processing (Codex Alimentarius, 2007; EC, 2016; USDA, 2016a; IFOAM, 2017a). Organic agriculture is characterised by an ecological approach to farming and by banning the use of synthetic fertilisers and pesticides (with pesticide, we refer to insecticides, herbicides, fungicides, etc.). Weeds are controlled through crop rotation, mulching, cover crops, hand weeding, and mechanical methods such as flame weeding. Pest control relies on agroecological practices (i.e. crop rotation, intercropping, soil management), biological control agents (i.e. predators, parasitoids, pathogens, and competitors), some traditional compounds, such as copper sulphate and lime, and natural compounds, with low toxicity for mammals, that quickly degrade in the environment.[1] The use of Genetically Modified Organisms (GMOs) is also banned. The organic movement aims to contribute to the health and well-being of farm animals. Organic regulations define the conditions that meet the high welfare standards set out by the organic principles.[2] Organic standards aim at minimising overgrazing, poaching of soil, erosion, or pollution caused by animals or by the spreading of their manure. In conventional agriculture, antibiotics are commonly used therapeutically and prophylactically, to prevent infections in livestock, as these can spread easily due to the high stocking density of animals under an intensive production regime (e.g., dairy cows, egg-laying hens). In some countries (e.g., the USA, Asian countries) antibiotics are also used as growth-promoters. The use of synthetic somatotropin, a growth hormone, is allowed in some countries, for example, in the USA, while it is forbidden in others, for example in Canada and the European Union (EU). Organic regulations forbid the use of hormones and antibiotics as growth-promoters, and severely restrict the use of antibiotics to special cases. Treated animals cannot be marketed as certified organic (a proper withdrawal time has to be respected). Regulations also concern many synthetic compounds that are used as food additives in the conventional food chain (e.g., preservatives, colouring agents) (EC, 2016; IFOAM, 2017a). Organic regulations, therefore, concern the whole food chain. It has to be noted that standards may vary between regions; EU standards differ slightly from USA standards, and there are also differences within the EU (different national certification bodies may follow different rules, within those set by the EU) (CERTCOST, 2012). Further to that, according to IFOAM (2017b), organic agriculture should also ensure fairness with regard to the shared environment and other living beings, and be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment. It has to be pointed out that the adoption of agroecological practices[3] (*i.e.* natural biological control of pests, integrating natural landscape elements into agricultural landscapes, reduced tillage, crop rotations) or low-input agriculture (*i.e.* reduced use of agrochemicals) can also greatly benefit the environment and reduce the use of agrochemicals (Altieri, 2002; Gomiero et al., 2011a,b; Wezel et al., 2014). Indeed, agroecological and low-input practices are fully adopted in organic agriculture. Nevertheless, these production systems are not certified by officially recognised certification bodies. The adoption of such farming practices is left to the farmers and practices may change from year to year, and the handling and processing phases of the food chain fall outside of such practices, while they are regulated and certified in the case of organic agriculture.

2.2. Organic agriculture: productivity and environmental impact

A number of reviews and meta-analyses have been produced concerning the productivity and environmental impact of organic systems compared to conventional systems. It is not within the scope of this work to deal with these issues in detail. Nevertheless, some information is briefly provided in order to make the reader aware of the present debate.

The capacity of organic agriculture to produce enough food, at an affordable price, to feed the present and future world population has been challenged, and, on this basis, the practical usefulness of organic agriculture itself is dismissed (Trewavas, 2001; Conway, 2012; Seufert et al., 2012; Tuomisto et al., 2012; Trewavas, 2004). On average, crop yields under organic management are reported to be 20–30% lower than the conventional counterpart, depending on the crops, agroecological context and practices (Gomiero et al., 2011a; Seufert et al., 2012; de Ponti et al., 2012; Ponisio et al., 2015; Gomiero et al., 2011b). Nevertheless, when comparing best organic practices/performances, Seufert et al. (2012) report a yield gap of about −13%, while de Ponti et al. (2012) report organic farming achieving the same, or even higher yields than conventional farming. A number of studies have shown that, under drought conditions, thanks to the better ability of organically managed soil to store water, crops in organically managed systems produce higher yields than comparable crops managed conventionally, up to 70–90% under severe drought conditions (Pimentel et al., 2005; Gomiero et al., 2011a; Gomiero, 2013). Ponisio et al. (2015) reported that when nitrogen inputs are similar between organic and industrial systems, the yield gap between the two systems is minimized. Some authors claim that organic agriculture may be also financially competitive (Reganold, 2012; Crowder and Reganold, 2015). A meta-analysis carried out by Crowder and Reganold (2015) found that total management costs were not significantly different for organic and conventional agriculture, but labour costs were significantly 7–13% higher with organic farming practices. Even though profits in organic agriculture were about 20–30% lower than conventional agriculture when organic premiums were not accounted for, organic agriculture was significantly more profitable (22–35%) than conventional agriculture when actual premiums were applied. If environmental services

[1] For example, pyrethrins (a class of organic compounds normally derived from *Chrysanthemum cinerariifolium*), insecticidal soap (based on potassium fatty acids), toxins produced by soil bacteria (i.e. *Bacillus thuringensis* and *Saccharopolyspora spinose*, the latter known as spinosad).

[2] For example, EC (2016 − Article 14 Livestock production rules) states that "*The husbandry practices, including stocking densities, and housing conditions shall ensure that the developmental, physiological and ethological needs of animals are met. … The livestock shall have permanent access to open air areas, preferably pasture…*"

[3] Agroecology has been defined as the holistic study of agroecosystems including all the environmental and human elements. It focuses on the form, dynamics and functions of their interrelationship and the processes in which they are involved (Altieri, 2002; Wezel et al., 2014). Agroecosystems are defined as communities of plants and animals interacting with their physical and chemical environments that have been modified by people to produce food, fiber, fuel and other products for human consumption and processing (Altieri, 2002).