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Review

Characteristics of Organically Grown Compared to Conventionally Grown Potato and the Processed Products: A Review

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Abstract: Interest in organic foods is increasing at a moment when humanity is facing a range of health challenges including the concern that some conventionally produced foods may pose possible adverse effects on human and livestock health. With the increasing human population, intensive production is increasingly trending towards high-input systems that aim to close yield gaps, increase crop yields, and develop new crop varieties with higher yield potential and tolerance to biotic and abiotic stresses, all within the context of incorporating specific traits to satisfy consumer demand. Potato (*Solanum tuberosum* L.) is one of the most consumed foods under different cultural diets, however its production faces some challenges related to soilborne diseases, marketable yield and quality, sugars and dry matter content of the produced tubers, tuber content in terms of nitrate, minerals, vitamins, bioactive compounds and antioxidants, and consumer appreciation regarding the sensory characteristics of tubers and processed products. Different studies have been investigating some of these challenges, with sometimes straightforward and sometimes connflicting results. This variability in research results indicates the general non-transferability of the results from one location to another under the same management practices in addition to differences in plant material. This review compares some characteristics of raw or boiled potato and processed products from potato tubers grown organically and conventionally. Ideally, such information may be of benefit in decision making by consumers in their dietary choices, by potato growers in their selection of crop management practices, and by scientists looking at potential areas for future research on potatoes.

Keywords: organic; conventional; potato; quality; disease

1. Introduction

Potato (*Solanum tuberosum* L.) is the fourth crop produced worldwide after rice, wheat and maize at the total annual production of 370, 504, 766 and 1,150 million tonnes for potato, rice, wheat and maize, respectively (FAOSTAT, 2021). Potato is adapted to a large range of geographical environments and climates (Horton and Anderson, 1992). Potato crop is very sensitive to water stress (Djaman et al., 2021, Zarzyńska et al., 2017; Romero et al., 2017), nitrogen fertilizer deficiency and is subject to different aboveground disorders and diseases [e.g., early blight (*Alternaria solani*), late blight (*Phytophthora infestans*), Fusarium dry rot (*Fusarium* spp.), black dot (*Colletotrichum coccodes*), potato virus

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Y, black leg (*Pectobacterium* spp.), aerial stem rot (*Pectobacterium carotovorum* subsp. *carotovorum*), ring rot (*Clavibacter michiganensis* subsp. *sepedonicus*), alternaria brown spot (Alternaria alternate)], and physiological disorders (e.g. growth cracks, knobs, misshapes, hollow heart, brown center) and soilborne diseases [e.g, Rhizoctonia canker and black scurf (*Rhizoctonia solani*), common scab (*Streptomyces scabiei*), powdery scab (*Spongospora subterranea* f. sp. *subterranean*), white mold (*Sclerotinia sclerotiorum*), silver scurf (*Helminthosporium solani*), pink rot (*Phytophthora erythroseptica*), Verticillium wilt (*Verticillium dahlia*), pythium leak (*Pythium* spp.), brown rot (*Ralstonia solanacearum*)] which tremendously impact tuber yield and the organoleptic quality of the harvested tubers and the processed products. Potato is consumed by humans under different preparations: boiled, baked, fried, snack, chips, starch and is a source of carbohydrates (Maggio et al., 2008; Warman and Havard, 1998), protein (Maggio et al., 2008; Moschella et al., 2005; Woese et al., 1997), minerals (Woese et al., 1997), vitamin C (Warman and Havard, 1998) and phenolic compounds (Woese et al., 1997).

Nitrogen availability to potato plants is critical to plant growth and development, tuber yield and quality. Nitrogen form and source are one of the main differences between conventional and organic potato production (Gastal and Lemaire, 2002; Wang et al., 2002; Van Delden et al., 2003; Lomardo et al., 2012, 2017). In addition, to control the numerous potential diseases and stabilize yield in potatoes, commercial growers apply a strict package of pesticides and high rate of nitrogen fertilizer (Mauromicale and Ierna, 1999; Maggio et al., 2008; Lombardo et al., 2012; Leonel et al., 2017; Djaman et al., 2019). Some undesirable residues can be accumulated in the potato tubers (Bacchi et al., 2004) and the soil (Navarro Pedreno et al., 1996) under conventional farming that can potentially affect human and animal health (Santamaria, 2006) and organic foods are therefore generally assessed as being healthier and of better taste than conventionally grown crops (Hajslova et al., 2005; Gilsenan et al., 2010).

The taste and bitterness are the main sensory properties of the boiled potato tuber and the texture, color and oil content, crispiness are the main quality parameters of fried potatoes (Aguilera, 1997; Moreira et al., 1999, Thygesen et al., 2001, Ross and Scanlon, 2004). Moyano et al. (2007) found a direct relationship between potato’s specific gravity, total solids content, starch content, cell size, and surface area and pectin and potato texture. For the processed product like potato chips, a very crispy texture is expected as crispness is an indicator of freshness and high quality (Moreira et al., 1999; Rosen and Hellenas, 2002; Troncoso and Pedreschi, 2007a,b). Mooreover, the color of the fresh, boiled or fried potatoes is considered one of the most important defining qualities, particularly of fried potatoes (Scanlon et al., 1994) and is the result of the Maillard reaction that is directly linked with the reducing sugars content and aminoacids or proteins at the surface, and the temperature and duration of frying (Marquezm and Anon, 1986).

For the present review, we compared some characteristics of the organically grown potato tubers to the conventional ones. We have considered only side-by-side comparative studies that include both organic and conventional farming practices to exclude some extraneous information which might not necessarily be the impact of the organic farming but the effects of uncontrolled factors. The main characteristics in our review focus on disease pressure on the potato plant and tubers, potato tuber total and marketable yields, specific gravity and dry matter content, sugar and starch contents of potato tubers, nitrate content of potato tubers, bioactive compounds and antioxidant contents in potato tubers, mineral and vitamin content, and the sensory characteristics of the potato tubers.

2. Weed and pest management

Weeds are a threat to any cultivated crop and negatively impact crop production as they compete with the planted crop for light, nutrients, water, and space and induce quantity and quality losses of the yield and ultimately decrease the net return of the production system with increased production costs. Potato cultivars with a strong, erect shoot growth habit with shorter stems, more branching, and a denser and taller canopy in the early stages of plant growth may be less susceptible to weed interference than cultivars with less lofty plant habit (Pszczółkowski and Sawicka, 2003; Baranowska et al., 2016; Barbaś et al., 2020). Commercial potato growers follow rigorous pesticide application schedules throughout the conventional potato growing season, and apply different pesticides. While conventional potato often starts by soil fumigation, organic potato often relies on the bio-fumigation provided by cover crops such as those of the Brassicacea family. Boydston (2010) reported that weeds should be managed in a holistic, intentional and proactive manner if no herbicide is considered. Under organic farming, crop rotation, cover crop selection, planting pattern and timing in addition to healthy and appropriate seed material are the main aspects to be considered for successful weed management. Some specific plants considered as cover crops such as sudangrass and different species of Brassica have been used as a green manure and biofumigant to reduce nematode populations preceding potatoes, and weed emergence (Boydston and Hang, 1995; Mojtahedi et al., 1993a,b). Cover crops that have reportedly suppressed weeds through direct competition or release of allelopathic compounds during decomposition of residues include: rye, oats, barley, rapeseed, mustards, sorghum-sudangrass hybrids, and buckwheat (Putnam and DeFrank, 1983; Weston et al., 1989; Lanfranconi et al., 1993; Boydston and Hang, 1995; Creamer et al., 1996; Boydston and Vaughn, 2002; Larkin and Griffin, 2007; Clark, 2007; Ngouajio and Mannan, 2005; Everts et al., 2006; Larkin and Halloran, 2014; Nyiraneza et al., 2015; Larkin et al., 2021). Mustard foliage (and seed) contain glucosinolate compounds that upon hydrolysis produce isothiocyanates, which act as natural bio-fumigants (Brown and Morra, 1997; Melrose, 2019, Rubel et al., 2020). However, multiple, well-timed shallow cultivations or heat-flaming can eliminate many early season weeds and the application of new technologies for detecting crop rows and weeds coupled with precision cultivation, flaming, and application of nonselective organic herbicides are being developed and hold promise to reduce the need for labor-intensive hand weeding (Boydston, 2010). Cover crops are planted by both organic and conventional potato growers for multiple objectives: nitrogen fixation, soil hydraulic properties improvement, diseases and nematodes suppression, adding more organic matter to the soil, nutrients reclamation, etc. (Hartsema et al., 2005; Clark, 2007; Campiglia et al., 2009; Griffin et al., 2009; Larkin et al., 2021). With cultivation as the only weed management practice in potato production, weed density increased with reduction in tuber yield compared to hand weeding or herbicide application (Eberlein et al., 1997; Felix et al., 2009). VanderZaag (2010) reported that weekly scouting of all fields to determine economic thresholds before spraying and the reliance on weekly newsletters informing about the status of pests and diseases offers significant, environmentally-friendly approaches for sustainable weed, pest and disease management across the potato field. The use of neonicotinoid chemistry as a seed tuber treatment greatly reduced the need to spray insecticide, especially for Colorado potato beetle control, and the amendment with cattle or swine manure led to better crop health and reduced the need for pest and disease treatments (VanderZaag, 2010). Herbicide selection, herbicide combinations and application rates and timing determine the effectiveness of the method in weed management (Pawlonka, 2007; Lavlesh Ragha et al., 2018; Zarzecka et al., 2020; Barbaś et al., 2020). Barbaś et al. (2020) found that chemical method of controlling weeds was the most effective weed control method over a combination of mechanical methods in potato production. However, the combination of metribuzin and rimsulfuron+SN oil as a potato pre-emergence tool was more effective than the other meribuzin, ethoxylated isodecyl alcohol 0.1%, fluazyfop-P butyl, SN oil combinations.

3. Nutrient management

Potatoes are a special crop and not only does the organic production system affect the crop plant growth and yield but also the tuber quality during cold storage is affected by the particular production systems. Organic farming faces many challenges such as proper nutrient management, weeds, diseases, and insect pest control (Finckh et al., 2006). Both organic and conventional systems have adopted cover cropping to improve soil organic matter content and improve soil quality. However, organic farming relies more on cover cropping to reduce weed pressure and some specific plant species (Brassicassae) are adopted for soilborne disease control in potatoes combined with improving nutrient and weed management under organic farming. Bio-fertilizers derived from microorganisms are an alternative to chemical and organic fertilizers. El-Sayed et al. (2015) compared mineral fertilizers at a rate of 285.6 kg N + 178.5 kg P_2O_5 + 357 K_2O /ha to a combination of bio-fertilizers consisting of nitrogen fixers (*Azospirillum brasilense* and *Azotobacter chroococcum*), P-dissolving bacteria (*Bacillus megaterium* and vesicular-arbuscular mycorrhiza) and K-dissolving bacteria (*Bacillus cereus*) plus different rates of compost on potatoes. They found significant increases in the total and marketable yield of potato from plots treated with 50% of the recommended mineral fertilizers plus 23.8 t/ ha compost with or without bio-fertilizer as well as from plots that received compost at the rate of 35.7 t /ha, compared with plots treated with full dose of mineral fertilizer plus 11.9 t/ha compost (control), while the compost treatment at the rate of 23.8 t /ha + bio-fertilizer resulted in a significant increase in marketable yield, and conventional fertilizer showed significantly higher weight loss of potato tubers during cold storage than all other treatments (El-Sayed et al., 2015). Mycorrhiza and *Azospirillum* as bio-fertilizers were found to reduce nitrate and nitrite contents of potato tubers (Hammad and Abdel-Ati, 1998; Abou-Hussein et al., 2002). Mycorrhizal potato plants were reported to show improved growth and development, pathogen resistance, and productivity compared to non-inoculated potato plants (Douds et al., 2007; Bharadwaj et al., 2008; Lone et al., 2015; Hijri, 2016; Chifetete and Dames, 2020). Khosravifar et al. (2020) inoculated potato plant with *Claroidoglomus etunicatum* and *Rhizophagus intraradices* and found that *R. intraradices* increased tuber yield by 32.48–36.00% compared to non-inoculated control plants with maximum root colonization percentage of 54.2%. Arbuscular mycorrhizal fungi are found to increase tolerance of potato plants to drought, salinity and disease by facilitating water and nutrient acquisition and by improving overall soil structure (Chifetete and Dames, 2020). Deja-Sikora et al. (2020) investigated the effect of joint Potato Virus Y infection and mycorrhizal colonization by *Rhizophagus irregularis* on growth traits of the host potato plant and found that the viral particles were concentrated in the leaves but decreased the root growth, and the infection with PVY evoked prolonged oxidative stress reflected by increased level of endogenous H_2O_2 and alleviation of oxidative stress in PVY-infected host plants by a substantial decrease in the level of shoot- and root-derived H_2O_2 with asymptomatic growth depression.

Carter et al. (2003) reported that the application of compost once in a 3-year potato rotation was beneficial for both soil physical and biological properties, and for potato productivity. However, due to the limited viability of compost and/or organic fertilizers in many locations and their low nitrogen content (Rembialkowska, 1999), organic fertilizer may be challenging and more emphasis should be given to cover cropping in addition to bio-fertilizers that colonize the soil under organic production in humid and sub-humid climates. The bio-fertilizers are constituted with microorganisms which solubilize the unavailable forms of inorganic-P (Venkateswarlu et al., 2007) and potassium rock through production and secretion of organic acids (Bin Zakaria, 2009). The leguminous cover crops are associated with nitrogen fixing bacteria *Azotobacter* spp. which are known to produce different growth hormones, vitamins and siderophores. *Azotobacter* is capable of converting nitrogen into ammonia, the form of nitrogen that can be taken up by plants (Kamil et al., 2008). Jen-Hshuan (2006) reported that *Azotobacter* spp. can produce antifungal compounds to fight against plant pathogens. Rees et al. (2011) reported that in-season fresh poultry manure amendment increased potato total yield compared to the fall application (Bationo et al., 2004). Lynch et al. (2008) reported the commercial hog manure–sawdust compost (CP) and pelletized poultry manure (NW) applied at 300 and 600 kg total N /ha positively affect potato tuber yield and potato plant N uptake (112 kg N /ha) under non-limiting soil moisture conditions. Fahmy et al. (2010) found that pulp fiber residue compost amendment increased potato plant-available phosphorus and potassium and the tuber yield was increased under supplementary irrigation while no change was observed in a rainfed setting compared to the non-amended plot. Green manure management and the recycling of organic materials may be a valid alternative to the conventional synthetic fertilizer-based management system for sustainable potato production, sustaining tuber yield without enhancing potential environmental risks due to N leaching (Canali et al., 2012). Drakopoulos et al. (2016, 2018) investigated solid cattle manure, lucerne pellets, grass/clover silage amendments on crop performance and nitrogen utilization of organic potato and found that plant-based fertilizers enhanced nitrogen utilization in terms of apparent nitrogen recovery compared to animal-based manures and the lucerne pellets resulted in the highest yield regardless of the tillage practices. In contrast, Wilson et al. (2019) reported that soil amendments with diverse wood waste and manure compost products resulted in a small increase in plant N availability in small plots experiments. The immature products resulted in net N immobilization, the composts high in K increased plant K availability with non-significant effects on tuber yield.

4. Potato diseases occurrence and intensity in potato

Disease management is a serious challenge and threat to organic potato management. Late blight, caused by *Phytophthora infestans* is commonly thought to be the factor most limiting yield under organic practices (Finckh et al., 2006). Soilborne potato diseases include Rhizoctonia canker and black scurf, caused by *Rhizoctonia solani*; common scab, caused by *Streptomyces scabiei;* powdery scab, caused by *Spongospora subterranea* f. sp. *subterranea*; white mold, caused by *Sclerotinia sclerotiorum*; silver scurf, caused by *Helminthosporium solani*; pink rot, caused by *Phytophthora erythroseptica;* and *Verticillium wilt,* caused by *Verticillium dahliae*. Common scab, caused by *Streptomyces scabies*; silver scurf *Helminthosporium solani* and softrot, caused by *Erwinia carotovora* var. *atroseptica* may be detrimental to organic production systems. Organic farming relies on the agricultural practices to reduce and/or control diseases instead of applying chemical pesticides. Larkin and Halloran (2014) indicated that disease levels and crop production are influenced by crop management practices. Disease pressure depends on crop physiology and nutrient availability that confers plant tolerance to disease stressors (Davies et al., 1993; Mulder and Turkensteen, 2005; Czajkowski et al., 2011; Dordas, 2008; Huber et al., 2012). Crop rotation plays a tremendous role in maintaining potato disease incidence at controllable levels. Through a process known as bio-fumigation, plants within the Brassicacae family produce glucosinolates, which break down into volatile compounds that are toxic to several plant pathogens (Sarwar et al., 1998; Kirkegaard and Sarwar, 1998; Matthiesen and Kirkegaard, 2006; Larkin and Griffin, 2007; Ngala et al., 2014; Melrose, 2019; Rubel et al., 2020; Vega-Álvarez et al., 2021). Tein et al. (2015) found potato common scab more severe under organic farming compared to the conventional farming during two seasons out of three. Conversely, the number of tuber infected by silver scurf was lower under organic farming while there was no significant difference between the farming system with regard to potato soft rot infection (Tein et al., 2015). Tein et al. (2015) found that the application of cattle manure in addition to catch crops increased the severity of silver scurf and common scab. However, the use of green and animal manures under organic farming rarely has a disease-increasing effect on soil-borne diseases infection and severity (Larkin and

Griffin 2007; Termorshuizen et al., 2006). The application of cattle manure overall increases the incidence of soilborne diseases (Bailey and Lazarovits, 2003; Bernard et al., 2014; Tein et al., 2015). Moore et al. (2014) pointed out that manure provides optimum conditions for common scab development by altering soil pH level. Tein et al. (2015) investigated the effect of management practices on potato tuber diseases (common scab (*Streptomyces* spp.), silver scurf (*Helminthosporium solani*), dry rot (*Fusarium* spp.), and soft rot (*Pectobacterium* spp.) and found that the organic systems had significantly more tubers (around 39 %) infected with common scab (surface cover 4–15 %) than in conventional systems (around 25 %), fewer tubers infected with silver scurf compared to all conventional farming systems, less tubers infected with dry rot in organic systems compared to the conventional systems, and the soft rot infections were not influenced by farming systems. Bernard et al. (2014) reported rapeseed rotation reduced all observed soilborne diseases such as stem canker, black scurf, common scab, and silver scurf by 10 to 52 % under organic farming.

Organic farming heavily relies on crop rotations and improved cropping systems incorporating management practices associated with soil health management (crop rotation length, cover crop species choice, and green manures, organic matter amendments, and minimum tillage). Larkin et al. (2021) found that disease suppression practices which included disease-suppressive green manures and cover crops, produced the highest yields compared to soil improvement, soil conservation and status quo practices representing yield increase from 11 to 35%. The disease suppression system consisted of a three-year rotation with the disease-suppressive Brassica "Caliente 119", Mustard Blend (blend of oriental and white mustard seeds, *Brassica juncea* L. and *Sinapis alba* L.) grown as a green manure, followed by a fall cover crop of rapeseed (*Brassica napus* L. " Dwarf Essex") in the first year (Larkin et al., 2021). In the second year, a disease-suppressive sorghum-sudangrass hybrid (*Sorghum bicolor* x *S. bicolor* var. *sudanense*) was grown as a green manure, followed by a fall cover crop of winter rye (*Secale cereale* L.), with potato in the third year. This combination improves disease control in potato with yield advantage. These organic management practices have been shown to significantly affect soil chemical, physical and biological properties (Ball et al., 2005; Karlen et al., 2006), as well as reduce soilborne diseases and increase crop productivity (Larkin, 2015). The use of *Brassica* spp. and sudangrass cover crops preceding potato planting reduces the pressure of the soilborne diseases on potato plant and the tuber (Larkin and Honeycutt, 2006; Larkin and Griffin, 2007; Larkin et al., 2010; Larkin and Halloran, 2014). The mechanism of action of the disease-suppressive crops used involves bio-fumigation, the breakdown of plant metabolites in soil to produce volatile toxic compounds that can reduce populations of weeds, nematodes and plant pathogens (Matthiessen and Kirkegaard, 2006; Larkin and Griffin, 2007; Snapp et al., 2007; Larkin, 2013, 2015; Larkin et al., 2016). Brassica crops species may change the soil microbial communities besides the bio-fumigation potential and reduce the soilborne diseases (Cohen et al., 2005; Larkin and Griffin, 2007; Larkin, 2013).

Table 1. Crop rotation impact on soilborne diseases and potato tuber yield.

Cover crops, compost, biostimulants	Diseases/nematodes/weeds	Disease control	Impact on tuber yield	Locations	References
barley	Rhizoctonia disease		decline in tuber quality	Canada	Carter and Sanderson (2001)
barley–red clover		Reduced	Yield increase	Canada	
'Lemtal' ryegrass	Rhizoctonia disease			Maine, USA	Brewer and Larkin (2003)
barley					Peters et al. (2004)

barley (undersown with red clover), red clover	stem and stolon canker, black scurf, silver scurf, dry rot, common scab	lower levels			
grass-clover	Late blight (*Phytophthora infestans*)		30%	Germany	Finckh et al. (2006)
winter wheat					
cabbage					
canola, rapeseed, radish, turnip, yellow mustard, and Indian mustard	*Rhizoctonia solani*, *Phytophthora erythroseptica*, *Pythium ultimum*, *Sclerotinia sclerotiorum*, and *Fusarium sambucinam*	80–100% in vitro		Maine, USA	Larkin and Griffin (2007)
indian mustard, rapeseed, canola, and ryegrass	powdery scab	15–40%,			
canola and rapeseed	canola and rapeseed	70–80%			
indian mustard green manure	common scab	25%			
rapeseed, yellow mustard, and 'Lemtal' ryegrass	black scurf	Reduced			
barley and ryegrass	*Rhizoctonia solani*	Reduced			
canola, rapeseed, and yellow mustard	black scurf	48–78%			
organic matter amendments	soilborne pathogens	suppressive in 45% and non-significant in 35% of the cases		Italy	Bonanomi et al. (2007)
flutolanil and *T. harzianum*	stem canker and black scurf	decreased the incidence of black scurf	marketable-sized tubers increased in yield from 35% to 60%	Finland	Wilson et al. (2008a)
Trichoderma harzianum	Stem canker and black scurf	reduced the severity of black scurf	fewer malformed and green-coloured tubers		Wilson et al. (2008b)
Mycorrhizae	Stem canker, black scurf	17-28%		Maine, USA	Larkin (2008)
aerobic compost tea +beneficial microorganisms	stem canker, black scurf, and common scab	18–33%	Increased by 20–23%	Maine, USA	
subclover and hairy vetch	weed suppression		Improved total and marketable tuber yield	Italy	Campiglia et al. (2009)
canola and rapeseed	Rhizoctonia canker, black scurf, and common scab	18 to 38%	6.8 to 8.2% higher	Maine, USA	Larkin et al. (2010)

barley, ryegrass, canola, and rapeseed	*Rhizoctonia* and other soilborne diseases	15–50%		Maine, USA	Larkin et al. (2012)
barley, ryegrass, canola, and rapeseed + rey	*Rhizoctonia* and common scab diseases	20-70%			
Brassica and sudangrass green manures, fall cover crops, and high crop diversity	soilborne diseases	25–58%			
biocontrol agents (*Bacillus subtilis GB03* and *Rhizoctonia solani* hypovirulent isolate *Rhs1A1*)	multiple soilborne diseases, stem and stolon canker	20–38%	no direct effect on yield	Maine, USA	Larkin and Tavantzis (2013)
	black scurf	30–58 %			
	common scab	10–34 %			
compost amendments from different sources	black scurf and commons scab	20–45 % increase of common scab	Total yield by 11–37 %; Marketable yield by 17–51 %		
Brassica napus	stem canker, black scurf, common scab, and silver scurf	10 to 52 %		Maine, USA	Bernard et al. (2014)
conifer-based compost amendment	stem canker, black scurf, common scab, and silver scurf	Variable	increase 9 to 15 %)		
mustard blend, sudangrass, and rapeseed	black scurf	16–27 %	6–11 %	Maine, USA	Larkin and Halloran (2014)
Mustard blend	common scab	11%			
mustard blend managed as a green manure	scurf	54 %	25 %		
barley + red clover	not specified			Canada	Nyiraneza et al.(2015)
barley–sorghum sudangrass +Brassica napus subsp. rapifera	not specified		significantly higher yields		
barley + *Brassica napus* susbsp. *Napus* + *Brassica napus subsp. Rapifera*	not specified		significantly higher yields		
Inhana Rational Farming: a complete Organic 'Package of practice' from Seed Sowing to crop Harvest	late blight (*Phytophthora infestans*)	higher 49.44 - 66.67% vs 2.82 to 7.91% under conventional		India	Bera et al. (2017)
Brassica rapa, Kale, Cauliflower, Broccoli, Cabbage	*Globodera rostochiensis*	Appreciable reduction in newly formed cysts		Portugal	Aires et al. (2009)
Brassica carinata	*Meloidogyne chitwoodi*	Reduced infection of tuber in field		USA	Henderson et al. (2009)
B. napus, *Raphanus sativus*	*M. chitwoodi*, *P. neglectus*	green manuring protected host	Increase in yield	USA	Mojtahedi et al. (1991,1993)

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		root against nematode infection for six weeks			
B. napus, *Raphanus sativus*	*M. chitwoodi*, *P. neglectus*	Declined population of both nematode species	Increase in yield	USA	Al-Rehiayani et al. (1999)
Sinapis alba	*G. rostochiensis*, *G. pallida*	Hatch inhibition of juveniles from cysts		The Netherlands	Scholte and Vos (2000)
Raphanus sativus	*Paratrichodorus teres*	Reduction in nematode population	Increase in tuber yield	The Netherlands	Hartsema et al. (2005)
Eruca sativa	*M. chitwoodi*, *M. hapla*, *P. allius*	Reduced nematode populations to non-detectable levels		USA	Riga et al. (2011)
B. juncea, *Eruca sativa*	*M. incognita*	increase in nematode population		South Africa	Engelbrecht (2012)
sorghum, Sudangrass	*M. incognita*, *P. penetrans*	Significant decline of *P. penetrans*, *M. incognita* populations were unaffected		USA	Everts et al. (2006)
T. erecta × *T. patula*, Sorghum-sudangrass	*P. penetrans*	Reduced nematode populations	increased crop yield	USA	LaMondia (2006)
white mustard (Sinapis alba) and oriental mustard (Brassica juncea)	Verticillium Wilt	25% and black scurf and common scab were reduced	12%	USA	Larkin et al. (2011)
sorghum-sudangrass hybrid	Verticillium Wilt	18%			
municipal solid waste compost	not specified		increased yield + macronutrients, micronutrients and heavy metals accumulation in the tubers	Spain	Escobedo-Monge et al. (2020)
compost of Municipal Solid waste with Leguminous Straw					
compost of Mixed Cow Manure with Leguminous Straw					
compost of Mixed Chicken manure with Leguminous Straw					
compost of Mixed Sheep with leguminous Straw					
arbuscular mycorrhizal fungi	not specified		marketable yield increase by +25%	Italy	Lombardo et al. (2020)

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5. Total tuber yield and marketable yield

Potato under organic production is subjected to different pests, diseases and limited available nutrient and consequently produces lower tuber yield compared to the conventionally grown potato (Clark et al., 1998; Offermann and Nieberg, 2000; Van Delden, 2001; VanDelden, 2001; VanDelden et al., 2003; Finckh et al., 2006; Möller et al., 2007; Haase et al., 2007; Lynch et al., 2012; Palmer et al., 2013). Synthetic fertilizers, pesticides and other non-organic inputs are not allowed under organic production which infers challenges in nutrient and pest management under organic farming than conventional systems with lower marketable potato tuber yield in organic production (Finckh et al., 2006; Lynch et al., 2008; Nelson et al., 2009; Rees et al., 2011). The yield of organically grown potato tubers is lower compared to the yield of the conventional grown potato by 5%–40% (Hansen, 2000; Razukas et al., 2008; Asakaviciute et al., 2013). Brazinskiene et al. (2014) reported potato yield under conventional production to be the double the equivalent yield under organic production of five Lithuanian potato varieties (VB Venta, Goda, VB Liepa, VBRasa and VB Aista). De Ponti et al. (2012) reported that organic tuber yield represents 80 % of conventional yield. Mourão et al. (2008), Lombardo et al. (2013) and Maggio et al. (2008) also indicated that potato tuber yield levels are typically lower in organic systems than in conventional high-input systems. Similarly, Kazimierczak et al. (2019) reported lower tuber yield of eight potato cultivars (Mazur, Justa, Lawenda, Lech, Tacja, Laskana, Otolia, Magnolia) grown under organic system compared to conventional system. Clark et al. (1998) reported that limitation in the amount of available soil nitrogen and the least complete and slower control of diseases explain the reduction in potato tuber yield under low-input systems. Maggio et al. (2008) found 25% reduction in potato marketable yield under organic system compared to the conventional system with higher percentage of large tubers under conventional system. Zarzyńska and Pietraszko (2015) have compared tuber yield of four potato cultivars (Viviana, Gawin, Legenda, Gustaw) grown under organic and conventional management practices and found that the organic system resulted in less than optimal plant growth, tuber yield and tuber size with the greatest number of small tubers under organic practices. From the six-year investigation of the effects of organic versus conventional crop management practices (fertilization, crop protection) and preceding crop on potato tuber yield and quality, Palmer at al. (2013) found that total and marketable yields were significantly reduced by the use of both organic crop protection and fertility management. Moreover, the yield gap between organic and conventional fertilization regimes was greater and more variable due to lower or less predictable nitrogen supply in organic fertilizer pratice than that between crop protection practices (Palmer et al., 2013). Ierna and Parisi (2014) reported that organic cultivation system was less productive (5 to 50% less) than the conventional due to a less availability of nitrogen and to appearance time and severity level of late blight infection. Fiorillo, et al. (2005) and Warman and Havard (1998) found no tuber yield reduction under organic farming. Warman (1998) suggested that variation in weather has a greater influence on productivity than the kind of fertilizer adopted.

6. Tuber specific gravity and dry matter content

Potato tuber specific gravity is an important characteristic for processing potatoes quality and it represents the dry matter content of tubers. Potato tuber with high specific gravity shows higher dry matter content and produces potato chips or fries with light color with less oil absorption (Lulai and Orr, 1997). Dale et al. (1994) and Haase (2004) indicated that the dry matter content of potato tuber linked with specific gravity is a main determinant of potato quality. Potato dry matter content has been grouped as high dry matter content

(≥ 20%), intermediate (between 18 and 19.9%), and low (≤17.9%) (Cacace et al., 1994). Dry matter content ≥ 20% and a specific gravity ≥ 1.08 are standard references of the processing industries (Haase, 2004; Kirkman, 2007). Lombardo et al. (2013) and Herencia et al. (2011) reported higher dry matter content in organically fertilized potatoes. Kazimierczak et al. (2019) also found high dry matter content in the potato tuber grown organically compared to the conventional production system. Moschella et al. (2005) have reported that tuber dry matter content is higher in organically than in conventionally grown potato. Similarly, Pither and Hall (1990) found higher dry matter in the organically grown potato tubers than the conventionally grown tubers. Lombardo et al. (2012) also reported similar findings. Woese et al. (1997) found no difference in potato dry matter content between the organically and conventionally grown potatoes.

7. Sugar and starch contents of potato tubers

Glucose and fructose are prevalent reducing monosaccharides with concentrations between 0.15% and 1.5% in potato tubers (Dramićanin et al., 2018) while the disaccharide saccharose is the most abundant sugar component in potatoes at a content between 0.4 to 6.6%, and other sugars are present in traces (Burton, 1989; Woolfe and Poats, 1987; Zommick et al., 2014). Starch is another large component of potato tubers (60–80% of potato dry matter) which defines the inner and or outer quality of the potato product (Storey, 2007). Arvanitoyannis et al. (2008) reported that the ratio of the starch content to the reducing sugars content is a quality index that determines the suitability of potato for industrial processing. Starch and reducing sugar content in potato tubers are considered as the nutritional quality by the consumers under increasing diabetes threat. However, the non-reducing sugars are converted into reducing sugars, and lead to the formation of acrylamide through a Maillard reaction with asparagines (Muttucumaru et al., 2015). Therefore, high content of glucose and fructose as reducing sugars in potato is an undesirable trait (Coleman et al., 1996; Haase, 2007; Leszkowiat et al., 1990; Ohara-Takada et al., 2005; Struik et al., 2007; Wang-Pruski, 2007). Reducing sugars accumulation in potato tubers occurs ordinarily only under organic systems (Maggio et al., 2008). From field experiment including four varieties, three environment and three farming systems (conventional, integrated and organic), Dramićanin et al. (2018) found that starch content in the potato tubers may be considered an important indicator of the type of production, botanical origin, and ripening time and the sugar macro- and microcomponents such as fructose, glucose, saccharose, sorbitol, trehalose, arabinose, turanose and maltose were the main factors for the differentiation of production types, production years and botanical origin of potato. Increase in total sugars was noted for organic potatoes when compared to conventional potatoes (Wszelaki et al., 2005; Hajšlová et al., 2005; Rembialkowska, 2007). In contrast, Leonel et al. (2017) reported that potato tubers fertilized with increased P exhibited a lower concentration of total sugar contents. Wadas and Dziugieł (2020) found that the use of plant biostimulant [the seaweed extracts Bio algeen S90 (*Ascophyllum nodosum*) and Kelpak SL (*Ecklonia maxima*), as well as the humic and fulvic acids] had a significant effect on starch content in potato cultivars Denar, Lord and Miłek tubers but did not affect the content of total sugars (glucose, fructose and sucrose), monosaccharides (glucose and fructose) or sucrose. In contrast, Grze ́skiewic et al. (1998) reported that the starch content of the potato tubers of the medium-early cultivar Muza was not affected by application of the Bio-algeen S90. Starch content in potato tubers of early cultivars Arizona and Riviera and medium-early cultivars Agria had increased under biostimulants based on *A. nodosum* extracts (Phylgreenmira, Algazone, Ultra-Kelp) (Al-Bayaty and Al-Quraishi, 2019). The humic substance molecular size, molecular characteristics and concentration affect the non enzymatic activities showing contradictory results of starch

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content in potato tubers (Selim et al., 2009; Canellas and Olivares, 2014; Suh et al., 2014; Alenazi et al., 2016; Conselvan et al., 2017; Ekin, 2019).

Lombardo et al. (2017) and Dramićanin et al. (2018) reported that the most abundant sugars in both the bulk and the peel potato were fructose, glucose and saccharose while sorbitol, trehalose, arabinose, turanose, galactitol, galactose, xylose, melibiose, maltose, gentiobiose, isomaltose, iso-maltotriose, ribose, panose, maltotriose were found in traces (Woolfe and Poats, 1987). Dramićanin et al. (2018) found significant effect of production type on the sugar content of potato tubers; the largest starch content in the peel (33.0%) and the bulk (78.1) of the tubers was observed in the conventional system, followed by the integral system with 28.2% and 67.5% in the peel and the bulk, respectively. The peel and the bulk potato grown under organic system had the lowest contents of starch with 22.7% and 65.2%, respectively. Tein et al. (2014) indicated that crop growth and development under conventional system are improved by extensive application of pesticides and fertilizers while under organic, the use of synthetic fertilizer and pesticides are not allowed. Lombardo et al. (2017) reported that the low starch content of potato tubers grown under organic system is due to the auto-consumption of part of the starch by the plant for its growth and development since no fertilizers are applied (Dramićanin et al., 2018). Dramićanin et al. (2018) found that potato tuber contents in glucose, fructose, sucrose, sorbitol, trehalose, arabinose, turanose, maltose and other simple sugars vary with the production systems with the highest content of the glucose, fructose and sucrose in the conventional system, followed by integral, and organic production systems. The starch and the sugar in potato tubers may be used as a promising tool in tracing the differences between potato cultivation systems, botanical origin and ripening time (Dramićanin et al., 2018).

8. Nitrate content of Potato Tubers

Organically grown potatoes generally contain less nitrate (Boligłowa and Gleń, 2003; Erhart et al., 2005; Lairon, 2009; Baranski et al., 2014) than conventionally grown potatoes. Lombardo et al. (2012) found that the nitrate content in the organically grown tubers was 34% less than in the conventionally grown potatoes. Similarly, studies have shown higher amounts of dry matter (Rembialkowska, 1999; Moschella et al., 2005), vitamin C (Hajšlová et al., 2005), total amino acids (Maggio et al., 2008) and total protein in conventional potatoes (Camin et al., 2007; Maggio et al., 2008), Bartova et al. (2013) also reported that organically produced potato tubers contained a significantly lower content of total nitrogen and crude protein compared to the conventionally grown potato. Kazimierczak et al. (2019) found higher concentrations of nitrates and lutein in conventional compared to the organic tubers of cultivars Mazur, Justa, Lawenda, Lech, Tacja, Laskana, Otolia, and Magnolia. The non-availability of nitrogen under organic farming as the higher soil content in nitrates increases the concentration of nitrates in plants (Montemurro et al., 2007). The non-availability of nitrogen under organic farming is compensated by the higher soil residual nitrogen content which increases the concentration of nitrates in plants (Montemurro et al., 2007). Bártová et al. (2013) reported that organic potatoes contained significantly lower nitrogen, nitrates and α-solanin contents compared to the conventionally grown potatoes while the protein and patatin contents were not significantly different between production management systems.

In contrast, Jiří et al. (2007) reported that mean contents of crude protein and in protein content in dry matter were significantly higher in organically grown potato tubers than in tubers from conventional practice. They found that potato genotype or cultivar was the factor with the highest direct effect on crude protein and protein contents in the potato tubers. Makaraviciute (2003) and Maggio et al. (2008) reported non-significant differences in potato content in essential amino acids between organic and conventional potato tubers. Shepherd et al. (2014) found that mass-spectrometry and gas chromatography analysis of polar compounds identified 83 metabolites showing significant differences in the metabolome between the organic and conventional farming with 62 metabolites (dominated by free amino acids) being less abundant in tuber samples from organic compared with conventionally grown plots due to the 50% lower nitrogen content of the organically grown potatoes than for conventional production. Lombardo et al. (2012) found that total protein amount was independent of the farming management system However, on the basis of peptide composition, protein quality as nutritional value is superior in the organically grown potato tubers than the conventionally grown potato tubers (Rembiałkowska, 2007).

9. Bioactive compounds and antioxidants content in potato tubers

Potato content in polyphenol increases under a stress condition as a protection response from the potato plant by producing large numbers of specialized compounds of secondary metabolism (Dixon and Paiva, 1995; Soltoft et al., 2010; Akula and Ravishankar, 2011; Ngadze et al., 2014; Brazinskiene et al., 2014; Veberic, 2016). Potato tubers contain important levels of bioactive compounds and antioxidants [4–8], including phenolic acids mainly chlorogenic acid with concentrations that vary from 49 to 1400 mg/kg dry matter (Akyol et al., 2016; Galani et al., 2017) ascorbic acid (Smith-Spangler et al., 2012; Lombardo et al., 2013; Lombardo et al., 2017), and flavonoids from 200 – 300 mg/kg of fresh mass which are phytochemicals helping to reduce the risk of several diseases, such as cardiovascular diseases, cholesterol reduction, and cancer (Friedman, 1997; Gumul et al., 2011; Smith-Spangler et al., 2012; Camire et al., 2009; Lombardo et al., 2013; Mangge et al., 2014; Akyol et al., 2016, Lombardo et al., 2017, Grudzińska et al., 2016; Pinhero et al., 2017; Beals et al., 2019). Polyphenols and other antioxidants are known to prevent cancers, cardiovascular disease, and various other diseases. Potato anthocyanins and phenolic acids suppress the proliferation of human melanoma and glioblastoma cells (Reddivari et al., 2007). Nichenametla et al. (2006) indicated that chlorogenic and ferulic acid decreased lung tumors in rats by 30%–40%. The anthocyanins and their aglycones present in red- and purple-fleshed potatoes have been found to exert proapoptotic and antiproliferative properties in gastric adenocarcinoma, colon cancer, and bovine aortic endothelial cells (Shih, et al., 2005; Stoner et al., 2006). Under limited nitrogen availability similar to organic farming systems, plant growth is limited and plant's metabolism shifts towards C rich compounds such as starch and phenolic compounds (Rembiałkowska, 2007). Vaitkevičienė et al. (2020) found higher contents of polyphenols, phenolic acids, chlorogenic acid, p-coumaric acid, cafeic acid, flavonoids and anthocyanins in potato tubers grown organically or biodynamically than in the conventionally grown potatoes cultivars Red Emmalie, Salad Blue, Violetta, Tornado, and Laura. Similar findings were reported by Kazimierczak et al. (2019), Jeon et al. (2005), Hamouz et al. (2005), and Baranski et al. (2014). However, phenolic content in the potato tubers depends on the genotypes, climatic conditions and conditions during storage period after harvest (Rodriguez-Saona, 1989; Stratil, 2006; Burmeister, 2011; Brazinskiene et al., 2014). Potato cultivar Violetta with a dark purple flesh, accumulated the highest contents of flavonoids, anthocyanins, petunidin-3,5-di-O-glucoside, pelargonidin-3,5-di-O-glucoside, and peonidin-3,5-di-O-glucoside. Colored potatoes are known for their sensory, nutritional value, and antioxidant activities as they are rich in polyphenols, anthocyanins, flavonoids, carotenoids, tocopherols, and vitamin C (Jansen et al., 2006; Vaitkevičienė et al., 2019). Tatarowska et al. (2014) found that carotenoids content in potato tubers was higher under organic production compared to the conventional production. Kazimierczak et al. (2019) reported significantly higher contents of flavonoids, quercetin, and quercetin-3-O-rutinoside in organically grown potato tubers compared to the conventionally grown potato tubers. Conversely, Brazinskiene et al. (2014) found that the farming system had no significant effect on phenolic acid concentrations in the potato tubers while Keutgen et al. (2019) found higher contents of phenolic compounds, flavonoids and ascorbic acid in organically grown potato tubers than the conventionally grown potato tubers. Romero-Pérez et al. (2001) found that flavonoids in plants are strongly impacted by genotype, the agroclimatic conditions, and the cultivation system. Lachman et al. (2009) and Vaitkevičienė et al. (2020) derived from their study that the colored-flesh potato genotypes have a greater impact on the anthocyanins content than the agricultural production system and they are not detected in white or yellow flesh potato tubers (Andre et al., 2007; Tierno et al., 2015; Vaitkevičienė et al., 2020).

On the other hand, Ezekiel et al. (2013) found no differences in phenolic contents in tubers grown in organic and integrated farming systems. Also, Grudzińska et al. (2016) and Lombardo et al. (2017) found higher total phenolics content in potato tubers under organic production. Lombardo et al. (2017) indicated that the higher concentration of phenolic compounds in the organically grown potato tubers was the result of diseases and pest pressure and lower nitrogen availability under organic farming. Phenolic compounds accumulations might be genoptype dependent. Keutgen et al. (2019) reported that the highest amounts of phenolic compounds were found in potato cultivar Satina (3.48 ± 0.57 g/kg of dry matter) as a genetic ability of that cultivar to accumulate phenolics. Similar findings were reported by Gugala et al. (2017). Similar development ability of flavonoids was reported by Keutgen et al. (2019). Smith-Spangler et al. (2012) and Grudzińska et al. (2016) reported higher ascorbic acid content in the organically grown potato tuber while Keutgen et al. (2019) found the opposite trend in their study and indicated that the discrepancy might be due to the limited availability of nitrogen in the organic production systems and the reduced above ground biomass, for the buildup of which photosynthates could have been used. Some studies reported that potato tuber content in ascorbic acid is cultivar dependent (Leo et al., 2008; Lombardo et al., 2012; Lombardo et al., 2019).

10. Mineral and vitamin contents

Potato tuber content might be impacted by soil and plant management practices. Wszelaki et al. (2005) found that potassium, magnesium, phosphorus, sulfur and copper concentrations in tuber skin and flesh, were also significantly higher in the organic treatments, while iron and manganese concentrations were higher in the skin of conventionally grown potatoes. Lombardo et al. (2014) investigated early potato tuber mineral contents under organic and conventional farming and found that the potato tubers contained more phosphorus (2.8 vs. 2.3 g kg^{-1} of dry matter) and a comparable quantity of both magnesium and copper (on average 250 and 2.6 mg kg^{-1} of dry matter, respectively) under organic farming than the conventional farming. Wszelaki et al. (2005) found tuber skin and flesh to have higher concentration in potassium, magnesium, phosphorus, sulfur and copper significantly higher under organic management than conventional practices while, iron and manganese contents were higher in the skin of conventionally grown potatoes.

Contradictory data have also been reported between the organically grown and conventional grown potato with respect to vitamin C content (Asami et al., 2003; Warman et al., 1998; Wacholder and Nehring, 1940). Warman and Havard (1998) found that there was no significant difference in vitamin C content of the potato tubers grown under organic and conventional practices. Conversely, other studies have reported higher vitamin C content in the organic potato tubers than in the conventional potato tubers (Rembialkowska 1999; Sˇtorkova ́-Turnerova ́and Prugar, 1988; Hajslova et al., 2005).

11. Sensory characteristics of the potato tubers

Crop management practices have not shown any significant effect on sensory properties of early potato cultivars tubers boiled (Brazinskiene et al., 2017), unpeeled tubers boiled in steam (Hajslova et al., 2005) or raw samples of potato (Dangour et al., 2009). Potato cultivar and production year are important influences on sensory quality of boiled potatoes (Hajslova et al., 2005). Potato skin might have significant property as consumers usually differentiate samples with skin from different cultivars as compared to samples without skin (Wszelaki et al., 2005; Muñoz et al., 2017; Asakaviciute and Razuka, 2020). Lombardo et al. (2012) found that potato cultivars Ditta and Nicola were well suited to boiling with a delicate taste, firmness and absence of blackening. Moreover, potato cultivars Arinda, Ditta and Nicola grown organically had a better sensory performance after frying (strong taste and crisp flesh) than the conventionally grown potato. There was no significant difference in farming systems with regards to consistency, typical taste after boiling (Hajšlová et al., 2005; Lombardo et al., 2012, Asakaviciute and Razuka, 2020), or typical taste after frying however, organically grown potato tuber showed higher crispiness and lower browning index (Lombardo et al., 2012). Woese et al. (1997) found no clear and consistent statements about the high sensorial quality of organic potatoes versus conventional potatoes from different studies on the organoleptic quality in organic practices compared to the conventional practices.

Potato threshold concentration in solanine of 140 μg g^{-1} causes bitter taste, and solanine concentration greater than 200 μg g^{-1} creates a burning sensations in the throat and on the tongue (Sinden et al., 1976). Gilsenan et al. (2010) found that the conventional potatoes had a lower dry matter content and a slightly softer texture than the organic potatoes. The conventional baked potato was also slightly softer, less adhesive and wetter than the organic backed potato but there was no significant difference between the organic and conventional baked potato samples for the sensory attributes of appearance, aroma, texture and taste acceptability (Gilsenan et al., 2010). Brazinskiene et al. (2014) reported that odor and taste intensity of the potato samples were not affected by farming practices.

Table 2. Comparative analysis of characteristics differences between organically and conventionally grown potatoes.

References	Major research findings	Locations
Warman and Havard (1998)	The yield and vitamin C content of the potatoes was not affected by treatments.	Canada
	P, Mg, Na, Mn contents in potato tubers and leaves N, Mg, Fe, B were influenced by treatments.	
Lombardo et al. (2012)	Potatoes from organic systems had 18% more total phenolics than those from conventional systems.	Italy
	The nitrate content in organically grown tubers was 34% lower than conventional products.	
	Ascorbic acid content of conventionally produced tubers were 23% greater than from organic systems.	
	Better sensory performance after frying (crispness and less browning) was observed in potatoes from organic than conventional systems.	
Brazinskiene et al. (2014)	Conventional farming yield is significantly higher than that obtained by organic.	Lithuania
	The farming type has no significant effect on the content of phenolic acids.	
	No significant effect of farming type on dry matter and starch content, or sensory properties was found.	
	The organic cultivation system was less productive than the conventional.	Italy

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Lombardo et al. (2014)	The organic farming produced tubers with a lower nitrate content, an important benefit in the context of human health.	
Soltoft et al. (2010)	Higher concentration of the phenolic 5-caffeoylquinic acid was detected in potatoes produced organically.	
Dramićanin et al. (2018)	The largest starch content in the peel and the bulk of the tubers was observed in the conventional system (33.0% and 78.1%, respectively).	Serbia
	The lowest contents of starch content in the peel and the bulk of the tubers were identified in the organic cropping system (22.7% and 65.2%, respectively).	
	The highest content of fructose, glucose, and saccharose in tubers was identified in the conventional system, followed by integral, and being the lowest in the organic cultivation system.	
Zarzyńska and Pietraszko (2015)	The organic production system resulted in less than optimal plant growth, tuber yield and tuber size.	Poland
Maggio et al. (2008)	Organic farming caused a 25% marketable yield reduction with a higher percentage of large tubers under conventional farming.	Italy
	Highest starch values were found in organic Merit and conventional Agria.	
	The total protein content was higher in both Agria and organically grown tubers and it also corresponded to higher total amino acid contents. Specifically, organic farming increased only threonine, whereas it significantly reduced most of the other amino acids.	
Larkin et al. (2010)	Incorporation of mustard residues (*B. juncea*) consistently resulted in greater effects on soil microbial communities and greater reductions in soilborne diseases than additions of other organic amendments.	Maine, USA
Vaitkeviciene et al. (2020)	Higher contents of polyphenols (sum), phenolic acids (sum), chlorogenic acid, p-coumaric acid, and cafeic acid were found in biodynamic and organic samples compared to the conventional tubers.	Poland
	Organically and biodynamically produced potatoes were significantly richer in flavonoids and anthocyanins.	
	Content of polyphenols (sum), phenolic acids (sum), chlorogenic acid, p-coumaric acid, caffeic acid, carotenoids (sum), lutein, and β-carotene showed no significant difference among the conventional and organic samples.	
	Organically and biodynamically cultivated potatoes (except the "Salad Blue" cultivar) were essentially richer in flavonoids and anthocyanins.	
Larkin et al. (2021)	Disease-suppressive green manures and cover crops, produced the highest yields overall under irrigation.	Maine, USA
Lombardo et al. (2017)	The organic cultivation system produced tubers of higher nutritional value, specifically exhibiting a higher total phenolic content (5.76 *vs.* 4.28 g kg^{-1} dry matter, averaged across locations and cultivars) and a lower nitrate content (0.64 *vs.* 1.04 g kg^{-1} dry matter, averaged across locations and cultivars), and displaying a more attractive color of both the skin and flesh.	Italy
Keutgen et al. (2019)	Organic farming was characterized by higher e antioxidant capacity.	Poland
	Better development of antioxidant properties of potato tubers in the organic cultivation system when compared with the integrated.	

	Potato tubers grown under two different production systems irrespective of location and variety or clone showed significant differences in the content of total phenolics, total flavonoids, ascorbic acid and citric acid.	
Palmer et al. (2013)	Total and marketable yields were significantly reduced by the use of both organic crop protection and fertility management.	England
	yield gap between organic and conventional fertilization regimes was greater and more variable than that between crop protection practices.	
Bartova et al. (2013)	Organic potatoes contained significantly less of nitrogen, nitrates and α-solanin.	Czech Republic
	Protein content, patatin relative abundance in total tuber protein and patatin content in organically produced potato tubers were slightly lower than in conventional ones but the differences were not statistically significant.	
Bernard et al. (2016)	Compost amendment had variable effects on tuber diseases, but consistently increased yield (by 9 to 15 %).	Maine, USA
	Rapeseed rotation reduced all observed soil-borne diseases (stem canker, black scurf, common scab, and silver scurf) by 10 to 52 %.	
	Combining rapeseed rotation with compost amendment both reduced disease and increased yield.	
Diviš et al. (2007)	Mean content of crude protein was significantly higher in tubers from organic crop management than in tubers from conventional system (10.92 and 9.76 % in dry matter, respectively).	Germany
	Cultivar was the factor having the highest direct effect on crude protein as well as protein contents.	
	Tubers from conventional crop management showed an increased tendency to accumulate nitrates.	
Moeller et al. (2007)	N availability was most important in limiting yields in organic potato crops.	Germany
	Only 25% of this variation in yield could be attributed to the influence of late blight.	
	In organic farming, yields are mainly limited by nutrient availability in spring and early summer.	
	The higher the N status of a potato crop, the longer the growing period needed to achieve the attainable yield and the higher the probability that late blight stops further tuber growth and becomes the key tuber-yield-limiting factor.	
Fiorillo et al. (2005)	Potato cultivars Aladin and Almera are suitable varieties for growers of Lazio region which are interested to switch from conventional to organic management system due to the highest marketable yield especially of medium size tubers (45-75 mm) and the low incidence of disease problems (common scab).	Italy
	Attacks of wireworm percentage incidence was almost 9 times higher in organic system in comparison to conventional system leading to a reduction of marketable yield of medium tuber size.	
Gilsenan et al. (2010)	The conventional potatoes had a lower dry matter content and a slightly softer texture than the organic potatoes.	Ireland
	No significant difference between the organic and conventional baked potato samples for the sensory attributes of appearance, aroma, texture and taste acceptability.	

12. Conclusion

This review has explored the characteristics of organically grown potato tubers compared to the conventionally grown potatoes. Across several studies comparing potato farming practices, it can be derived that potato total tuber and marketable yield is lower under organic farming than under conventional farming. Weed and disease pressure is more intense under the organic farming and the lower nitrogen available for potato plant infers low nitrogen content in the organically grown potato tuber. Organic potato tubers contain higher sugar content compared to the conventionally grown tubers. Organic potato tubers show high polyphenol compounds content due to the stress occurring under the organic practices (limited nutrients and increasing disease pressure) compared to the conventional practices. Some contradictory results are reported on the impact of cropping systems on potato tuber content in minerals, vitamin C, sensory properties and the dependence of several characteristics on the genotypic material. For future studies, it is crucial to match the best agronomic production practices and plant genotypic material to maximize the fresh potato and processed products contents in bioactive compounds to match the health-promoting properties for more production sustainability. Consumers are showing increasing interest in organically grown potatoes due to its nutritional quality and health protection value. Due to the lower tuber yield under organic farming, for the profitability of the production system, organic products are more expensive and consumers might be willing to pay the price for health-promoting properties.

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