agronomy

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Overall Quality of "Early" Potato Tubers as Affected by Organic Cultivation

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Abstract: Understanding the nature of the perceived quality advantage of organically-grown early crop potatoes over conventionally-grown ones is of relevance given the expansion in demand for foodstuffs produced by environmentally friendly agricultural practices. The effect of the cultivation system (organic vs. conventional) on physicochemical (skin color, firmness, skin thickness, pH, titratable acidity), nutritional (dry matter, ascorbic acid, total phenolics content, antioxidant activity), and sensorial (for boiled and fried tubers) traits of early potatoes were explored in a field trial conducted during two-seasons in Sicily (Southern Italy) and involving five yellow-fleshed genotypes. The organic cultivation system, averaged across seasons and genotypes, produced tubers displaying a more attractive skin color, with higher skin thickness and firmness, higher dry matter content (19.0 vs. 17.9%), and total phenolics content (350 vs. 232 mg GAE 100 g^{-1} dry weight) but lower ascorbic acid content (76 vs. 103 mg 100 g^{-1} dry weight) and antioxidant activity (42 vs. 56% DPPH reduction). The organic cultivation did not affect attributes after boiling but improved all sensory attributes (crispness, typical taste, and browning degree) after frying, highlighting that the superiority of the organic potatoes does not cover all aspects of quality. The positive effects of organic cultivation on physicochemical, nutritional, and sensorial quality were particularly evident in Arinda, Ditta, and ISCI 4F88. Even if the response of organic cultivation on overall quality also depended upon seasonal conditions, cultivar choice plays a key role in optimizing this production system, highlighting the importance of breeding programs.

Keywords: *Solanum tuberosum* L.; organic; conventional; quality; genotype; season

Citation: Ierna, A.; Parisi, B.; Melilli, M.G. Overall Quality of "Early" Potato Tubers as Affected by Organic Cultivation. *Agronomy* **2022**, *12*, 296. https://doi.org/10.3390/agronomy12020296

Academic Editor: Richard G. F. Visser

Received: 20 December 2021
Accepted: 20 January 2022
Published: 24 January 2022

1. Introduction

The potato (*Solanum tuberosum* L.) is a very important crop as a staple food in the Mediterranean Basin, occupying an overall area of approximately one million ha and producing 28 million tons of tubers [1], mainly as off-season product in the period from March to June to take advantage of the early crop potato market [2]. Early potatoes are highly appreciated for their freshness as well as for their nutritional quality, above all as a source of vitamins (e.g., ascorbic acid) and phenolic compounds [3], which, because of their antioxidant properties, may exert beneficial effects on human health [4]. The high commercial value of the product prompts potato growers to adopt major farming inputs, which have undoubtedly been responsible for increased early potato yields in recent decades [5]. Moreover, conventional cultivation can result in undesirable residues in both the tubers and the soil [6]. As a result, the share of the harvest of early potatoes taken from organic producers has increased, also because organically grown early potatoes can be sold at a price far higher than that of the conventionally-grown equivalent, attributable to the fact that their quality is perceived as superior. The improved qualitative value of organic vs. conventional produce, however, has not been ascertained. Controversial and opposite data between organically and conventionally grown were found in main crop potato tubers for nutritional and antioxidant compounds [7,8]. Moreover, results on the effects of the organic cultivation system on quality characteristics of tubers from main crop potatoes reported in the literature cannot be used for "early" potato crops since they are harvested before their full 'ripening' at a more or less advanced growth stage and so differ qualitatively from main crop ones [9]. In addition, "early" potatoes come from off-season crops, in which weather conditions throughout the entire crop cycle are completely different than the main crop, therefore, potentially altering crop development and growth [10]. Early potatoes are mainly used for the fresh market making traits related to appearance very important, such as skin color, which could affect sensory perception and consumer acceptance [11]. Research about the effects of organic cultivation on skin color and nutritional characteristics of early potatoes have shown that they depend on genotype choice and seasonal conditions [12–15]. Cultivar choice needs to be directed to those which can yield reliably under a low input regime while maintaining a high level of tuber quality. On the other hand, for potatoes, the sensory evaluation of the flesh traits of cooked tubers are other important parameters that could greatly influence consumer choice [16]. The agronomical practices used in organic production systems are significantly different compared to conventional ones and may result in altering qualitative parameters [7]. In this respect, controversial data have been published concerning sensory quality of cooked tubers [8,17,18]. Thus, understanding the effects of organic cultivation on the sensory profile of cooked tubers would be important for early potato growers who could differentiate their products to match the demand of the national and international market and improve their commercial value. In addition, in organically grown potato crops, climatic conditions may affect tuber quality mainly due to their effect on mineralization rates from organic matter in soil which involves lower nutrient availability for the crop since mineralization is known to depend on both soil temperature and moisture. Under the cool temperate climate, precipitation patterns over the winter period could affect leaching losses and thereby nitrogen availability to spring-planted organically fertilized potato crops, which may be also susceptible to restricted nitrogen mineralization due to low spring temperatures [19].

Considering that the success of a cultivar for organic cultivation depends on the overall product quality to match the demand of the national and international market, further knowledge on tuber quality traits of new potato genotypes considered suitable for organic farming could be important. The present research aimed to evaluate the effects, over two years, of the cultivation system (organic vs. conventional) on the physicochemical and nutritional quality of the raw material and the sensory profile of cooked tubers of different genotypes from early potato crops.

2. Materials and Methods

2.1. Site, Climate, and Soil

Experiments were carried out over two growing seasons in 2011 and 2012 (hereafter referred to as season I and season II, respectively) at our experimental field on the coastal plain south of Syracuse (37°03′ N, 15° 18′ E, 15 m a.s.l.). This is a typical area for off-season potato cultivation in Italy. The climate is the semi-arid Mediterranean characterized by mild winters and commonly rainless springs. The soil type is Calcixerollic Xerochrepts (USDA). Soil analyses were made before the start of the trials in a layer 0.25 m thick (from 0.05 to 0.30 m) which indicated the following characteristics: clay 27%, silt 40%, sand 33%, organic matter 2.3%, pH 7.6, total nitrogen 1.5‰, available P_2O_5 53 kg ha^{-1}, exchangeable K_2O 366 kg ha^{-1}. All analyses were performed according to procedures approved by the Italian Society of Soil Science [20]. The plots used for organic cultivation were fully converted to organic farming in 2001 by a three-year transition period with crop rotation including potato, faba bean, and globe artichoke. The conventional plots (involving the same crop rotation) were separated from the organic ones by a distance of 50 m.

2.2. Experimental Design, Plant Material, and Crop Management

Over two growing seasons in each cultivation system: Conventional (**Con**) and Organic (**Org**), the plant material was arranged in a randomized block experimental design with three replications. Each block included five genotypes (Arinda, Bionica, Ditta, ISCI 4F88, and Marabel) with a plot size of 4.9 m $\times$ 4.5 m with 105 plants. Arinda and Marabel are cultivars well-adapted to Mediterranean growing conditions more used for the conventional production of "early" potato crops [21]. Ditta is a salad-type cultivar well-known and popular among the Italian organic potato growers' market oriented to export to Germany. Bionica is a recent table stock variety specifically targeted for the organic potato market. ISCI 4F88 is a new Italian breeding clone from the potato breeding program at the Research Centre for Cereal and Industrial Crops (CREA-CI) in Bologna (Italy), focused on the release of new potato genotypes well-adapted to organic farming systems. The main characteristics of tubers in the five genotypes are reported in Table 1.

Table 1. Main tuber characteristics of the five genotypes under study.

Genotype	Shape	Skin Color	Pulp Color	Cooking Type [1]
Arinda	long oval	yellow	yellow	B
Bionica	oval	yellow	cream	AB
Ditta	long oval	yellow	yellow	A
ISCI 4F88	oval	yellow	yellow	B
Marabel	oval	yellow	yellow	B

[1] According to the European Association for Potato Research (EAPR) cooking type scale: A, firm texture (suitable for steaming, microwaving, and boiling); B, mealy texture (multi-purpose cooking).

In the two growing seasons, organic and conventional certified A class sprouted seed-tubers were hand-planted at 0.3 m in the rows and 0.7 m between the rows (equivalent to a plant density of 4.76 plants m^{-2}). Planting was on the 2 of February in season I and the 31 of January in season II. Throughout the two seasons, the **Con** cultivation system was managed according to local farming practices and the **Org** cultivation system followed current EU regulations. Details on crop management in conventional and organic cultivation are given in Table 2.

The same fertilizer regime was applied in **Con** and **Org**, 100 kg ha^{-1} N, 70 kg ha^{-1} P_2O_5, and 150 kg ha^{-1} K_2O, in the form of either NPK synthetic fertilizer (**Con**) or a mixture of meat and bone meal and dried manure-based commercial products (**Org**); the level of mineral fertilization used coincides with the early potato crop uptake determined in the same environment in a previous study [5]. Drip irrigation was initiated once the accumulated daily evaporation rate had reached 40 mm and the total water supplied was 180 mm and 150 mm in seasons I and II, respectively. Tubers were harvested manually when the leaves and stem were bleached and dry (at 111 DAP in season I and 114 DAP in season II). Tubers were selected by diameter classes (Φ < 35 mm, 35–70 and >70 mm), then were counted and weighed to determine total yield and average tuber weight. Tubers mechanically- or slug-damaged, affected by growth cracks or tuber blight or green, and tubers weighing less than 20 g were weighed together and considered discarded product. Tuber yield was lower under the **Org** compared to the **Con** system (18.7 vs. 23.0 t ha^{-1}). The differences in yield between **Con** and **Org** were higher in season I ($-$25%) than in season II ($-$13%). In season I, in both the organic and the conventional systems, a late blight infection occurred caused by *Phytophthora infestans*, which determined yield loss and discarded product higher in **Org** than in **Con**, attributable to less effective plant protection in organic. Details on tuber yield loss and discarded product were extensively reported in a previous paper [12].

Table 2. Crop management of the two cultivation systems under study.

Cultivation System	Type	Active Ingredient	Phenological Stage
Conventional	Herbicides	Clomazone	Pre-emergence
	Pesticides	Benfuracarb (wireworms)	Before planting
		Cimoxanyl, Dimetonorf, zoxamide (late blight)	During crop growth
		Cipermethrin (aphids)	During crop growth
		Imidacloprid (colorado bittle)	During crop growth
	Fertilizers	Superphosphate, Potassium sulphate	Before planting
		Ammonium nitrate	At complete emergence and tuber initiation
Organic	Herbicides	No (hand-holing)	
	Pesticides	Tribasic copper sulphate (late blight)	During crop growth
	Fertilizers	Meat and bone meal based (a) and dried manure based (b) commercial products	Before planting

(a) composition: organic N 7%, total P_2O_5 7%, total Fe 0.8%; (b) composition: organic N 3.5%, total P_2O_5 1.5%, total K_2O 1.5%, total CaO 5–8%, total MgO 0.8–1%, and microelements.

2.3. Sample Collection and Preparation for Analysis

At least fifty tubers per replicate for each genotype and cultivation system were selected from a representative sample of marketable tubers (Φ 35–70 mm) which were of uniform size and were disease-free. They were washed with tap water to remove any soil, then in distilled water, and dried with tissue paper. All reagents were purchased from Sigma-Aldrich (Milan, Italy) and solutions were prepared in double-distilled water. All analyses were performed in duplicate. Tubers were subjected to physico-chemical, nutritional, and sensorial analyses after cooking.

2.4. Physico-Chemical Analyses

Color readings were performed on the surface of five whole tubers per plot using a Minolta colorimeter (CR–300; Minolta, Osaka, Japan) equipped with a standard illumination D65 with measurements replicated three times. Measurements were quantified in L (lightness), a (redness), and b (yellowness) specified by the Commission Internationale de l'Eclairage [22]. From these values, chroma (C) and hue angle (h°) were calculated based on $C = (a2 + b2)\ 0.5$ and $h^\circ = \arctan(b/a)$. While h° is useful to quantify the hue expressed by an object, C is something analogous to color saturation [23].

Firmness was evaluated in the middle part of four tubers by a digital penetrometer (model 53205, TR Turoni and C. snc, Forlì, Italy) fitted with a cylindrical probe of stainless steel with a screwdriver. Data are the mean of the maximum force (N) required to penetrate the tuber to 3 mm. Measurements were recorded in kg cm^{-2}.

Skin thickness was determined on four tubers per plot. Each tuber was peeled with a potato peeler, the skin and peeled tuber were placed in a thermoventilated oven at 105 °C until constant weight and were weighed. Skin thickness was calculated as the percentage incidence of the dry weight of the skin on the dry weight of the skin + dry weight of the peeled tuber.

Five whole tubers were peeled and ground by mortar and pestle quickly. The homogenate was analyzed for the pH and titratable acidity. The pH was determined by potentiometric measurement on 100 g of pulp at T = 20 °C with a pH meter (pHmeter InLab pH Level 1, WTW, Weilheim, Germany) [24]. Titratable acidity was determined on 50 g of pulp by titration to pH 8.1 with a 0.1 N sodium hydroxide solution with alcoholic phenolphthalein as an indicator and expressed as mg of anhydrous citric acid 100 g^{-1} dry weight (mg 100 g^{-1} DW) [24].

2.5. Nutritional Analysis

Five tubers per replicate were sliced into 10 mm wide strips of differing lengths. The sample was oven-dried at 65 °C, until constant weight was achieved [24] to determine the dry matter content, which was expressed as %. Five tubers per replicate were peeled and ground by mortar and pestle quickly. The homogenate was analyzed for the following parameters: ascorbic acid, total phenolics, and antioxidant capacity. Ascorbic acid content was quantified using the 2,6-dichlorophenolindophenol (DCPIP) dye method [24]. Fifty grams (50 g) of pulp were placed in a conic flask with 50 mL of 8% (*v*/*v*) acetic acid and 50 mL of 3% (*w*/*v*) metaphosphoric acid, vigorously shaken and filtered. Then, an aliquot (10 mL) of the filtrate was titrated with DCPIP until the development of a rose pink color. Results were expressed as mg of ascorbic acid (AA) per 100 g^{-1} of dry weight (mg 100 g^{-1} DW). The content of total phenolics was analyzed spectrophotometrically using the Folin–Ciocalteau colorimetric method reported previously [25]. Five whole tubers per replicate were peeled and were chopped into small pieces with a sharp stainless steel cutter to facilitate extraction; the chopped tissue was ground in a mortar and pestle. Total phenolics analysis was carried out on five grams of these powders. The tissue was diluted 10-fold with ethanol/distilled water (50% *v*/*v*), was stirred and then precipitated by centrifugation. On 1 mL of supernatant (extract), after 1 h of dark chemical reaction with Folin–Ciocalteu phenol reagent (Sigma-Aldrich, Steinheim, Germany) and Na_2CO_3, the absorbance at 710 nm was obtained against a blank, which had been prepared similarly by replacing the extract with distilled water. Total phenolic content was calculated from a calibration curve using gallic acid as the standard. Results were expressed as mg gallic acid equivalents (GAE) per 100 g^{-1} of dry weight (mg GAE 100 g^{-1} DW). Antioxidant capacity was evaluated in methanolic extracts using the DPPH (2.2-Diphenyl-l-pict3,1hydrazyl) free radical-scavenging assay according to the methodology described by Brand-Williams et al. [26] with modifications. 100 µL of potato extract (1 g mL^{-1} in methanol) was mixed thoroughly with 2 mL of freshly prepared 0.1 mmol L^{-1} DPPH methanolic solution. After incubation at room temperature for 60 min in the dark, the absorbance at 517 nm was measured in a spectrometer (Lambda 11, Perkin Elmer, San Jose, CA, USA). Methanol (100 µL) without the extract was used as a blank. The capability to scavenge the DPPH radical was calculated as follows: DPPH-scavenging effect (%) = $[1 - (A_{517,\,sample}/A_{517,\,blank})] \times 100$.

2.6. Sensorial Analysis of Cooked Tubers

Sample Preparation

For boiling, ten tubers for replication were peeled manually using a potato peeler, rinsed and drained. Chosen for this purpose were tubers from the two cultivation systems of similar weight, which were approximately 80 g for Arinda, ISCI 4F88, and Marabel, 90 g for Bionica, and 70 g for Ditta. Then, they were longitudinally halved and boiled in unsalted water using a 7.0-L capacity household pressure cooker (Lagostina S.p.A., Omegna, Italy) for 15 min. For frying, a sample of ten pre-peeled tubers for replication was pushed through a vegetable slicer to obtain, from the core region, two sticks of uniform size (section 8 × 8 mm) trimmed to a length of 10 cm. After draining excess water, these sticks were fried in peanut oil at a constant temperature of 180 °C for 5 min using a fryer (Kastel SpA, Treviso, Italy). Both boiled and fried samples were separately placed on a white covered plate, coded by a three-digit random number, and kept in a heating chamber at 60 °C before sensory evaluation.

The sensory attributes of cooked potato samples were evaluated by a panel of eight judges (four women and four men, all members of CNR, section of Catania, and aged between 25 and 60 years), screened for the ability to perceive sensory attributes (basic taste, odor detection, and color vision including blackening and browning phenomena after cooking) and communicate them. Before the analysis sessions, panelists were trained to assess the aptitude of potato tubers to boiling and frying. Two separate sensory sessions (one per day) were held in season I and II, one for each cooking preparation. All samples, prepared as above, were analyzed in duplicate and were individually served in a randomized order within 30 min after cooking preparation at a temperature between 40 and 60 °C. Each judge assessed two quartets of boiled tubers and five sticks per replicate and was instructed to eat crackers and drink water as palate cleaners and pause for 30 s between sample evaluations. For suitability to boiling, panelists were asked to score the samples as the following: consistency (1–5 = from very tender to very hard), typical taste (1–5 = from absent to very pronounced), and after cooking blackening index (0–2 = from absence to widespread blackening). For the assessment of culinary aptitude to frying, the following descriptors were considered: crispness (1–5 = from absent to very pronounced), typical taste (1–5 = from absent to very pronounced), and browning index (assessed through the certified Munsell colorimetric paper). The values of the latter were adjusted from USDA to CISA category: 000 = 0 (extra white, no browning); 00 = 1 (white or cream, no browning); 0 = 2 (yellow, no browning); 1 = 3 (light browning); 2 = 4 (browning); 3 = 5 (average-high browning); 4 = 6 (complete browning).

2.7. Weather Conditions during the Trials

During season II, mean maximum and minimum temperatures in the period from February to May were lower than season I (18.4 vs. 20.2 °C and 10.6 vs. 12.4 °C, respectively). Season I was more typical as compared to the long-term climate, experiencing similar maximum and minimum temperatures during the growing period. However, rainfall in season I was higher (approximately 260 mm, of which 150 mm was in March) than both season I (137 mm) and a 30-year (1977–2006) period (114 mm) (data not shown). The higher maximum and minimum temperatures and total rainfall during season I presumably created the optimal conditions for the development of the late blight infection.

2.8. Statistical Analysis

Bartlett's test was used to test for homoscedasticity, following which the data were subjected to a three-way (cultivation system × genotype × season) factorial analysis of variance (ANOVA). Provided that the *F* test was significant, means were separated on the basis of Fisher's protected least significant difference test.

3. Results and Discussions

Results of the analysis of variance for all studied variables are reported in Table 3.

Table 3. *F*-values resulting from ANOVA for all studied variables.

Source of Variation	Cultivation System (CS)	Genotype (G)	Season (Se)	CS × G	CS × Se	G × Se
Lightness SK	29 ***	6 ***	1 NS	5 **	5 **	1 NS
Chroma SK	8 **	11 ***	0.02 NS	3 *	34 ***	0.06 NS
Hue angle SK	10 **	14 ***	2 NS	4 *	0.1 NS	0.08 NS
Skin thickness	75 ***	28 ***	22 ***	8 ***	8 **	2 NS
Firmness	36 ***	7 ***	16 ***	3 **	5 NS	5 **
pH	171 ***	38 ***	1 NS	1 NS	5 NS	1 NS
Titratable acidity	138 ***	14 ***	319 ***	7 ***	13 NS	20 ***
Dry matter	40 ***	38 ***	28 ***	4 **	6 NS	10 ***
Ascorbic acid	96 ***	86 ***	14 ***	29 ***	8 **	11 ***
Total phenolics	176 ***	82 ***	72 ***	7 ***	34 ***	22 ***
Antioxidant activity	100 ***	40 ***	116 ***	8 ***	19 ***	13 ***
Consistency AB	2 NS	26 ***	3 NS	2 NS	0.04 NS	1 NS
Typical taste AB	6 **	12 ***	4 NS	3 NS	0.07 NS	1 NS
Blackening AB	-	-	-	-	-	-
Crispness AF	33 ***	54 ***	7 **	19 ***	2 NS	1 NS
Typical taste AF	36 ***	18 ***	10 **	12 ***	3 NS	0.5 NS
Browning index AF	51 ***	66 ***	8 **	5 **	6 NS	0.6 NS

Values are given as *F* of Fisher - Snedecor test; ***, ** and * indicate significant at $p < 0.001$, $p < 0.01$ and $p < 0.05$ respectively, NS not significant. SK skin color; AB after boiling; AF after frying.

Here, as shown in Table 3, all qualitative traits (physico-chemical, nutritional, and sensorial) were influenced by the cultivation system and genotypes and by the interaction between these two factors, except the pH and the sensorial characteristics of tubers after boiling.

The lightness, chroma, and skin thickness, as well as ascorbic acid content, total phenolics, and antioxidant activity were also affected by the 'cultivation system × season' interaction.

3.1. Physico-Chemical Traits

Skin color is an important trait of the consumer's perception of tuber quality. Regardless of season and cultivar, lightness, chroma, and hue angle were consistently higher for **Org-** than for **Con**-grown tubers, with the former displaying a more bright and vivid appearance of skin (Table 4), which is in agreement with the results of Lombardo et al. [15]. **Org**-grown tubers of 'Bionica' and 'Ditta' showed a more brilliant color and a major yellow component of the skin compared to the **Con**-grown ones (Table 5). In addition, lightness and chroma were also significantly influenced by the 'cultivation system × season' interaction (Table 6), showing a greater increase in the lightness and chroma values in season II compared to season I. This may be attributed to the cooler temperatures experienced in season II which may have emphasized the pigmentation differences observed between the two cultivation systems [27].

Table 4. Physico-chemical and nutritional quality of early potatoes as affected by cultivation system, genotype, and season.

	1	2	3	4	5	6	7	8	9	10	11
Cultivation System											
Conventional	60.7 b	25.4 b	86.8 b	6.6 b	2.19 b	6.0 a	199 a	18.4 b	103 a	221 b	56 a
Organic	64.2 a	26.7 a	88.2 a	8.0 a	2.32 a	5.7 b	156 b	19.6 a	76 b	333 a	42 b
Genotype											
Arinda	60.2	24.8 b	85.0 b	7.6 a	2.33 b	6.1 a	164 b	17.9 c	114 a	180 d	54 b
Bionica	62.2	25.0 b	87.9 a	7.2 ab	2.27 bc	5.7 c	189 a	18.3 bc	104 b	266 b	59 a
Ditta	62.8	28.1 a	89.0 a	7.6 a	2.12 cd	6.0 a	165 b	19.0 b	97 b	348 a	45 c
ISCI 4F88	65.2	27.6 a	89.5 a	7.4 a	2.58 a	5.6 c	197 a	20.8 a	78 c	371 a	42 c
Marabel	61.8	24.7 b	86.2 b	6.6 b	1.98 d	5.9 b	172 b	18.8 b	56 d	191 c	35 d
Season											
Season I	62.4 a	26.1 a	87.4 a	7.5 a	2.39 a	5.9 a	145 b	19.6 a	88 a	313 a	40 b
Season II	62.5 a	26.0 a	87.6 a	7.1 b	2.13 b	5.8 a	209 a	18.4 b	91 a	241 b	54 a

Different letters within each column indicate significance at Fisher's protected LSD test ($p < 0.05$). 1: Skin lightness; 2: Skin chroma; 3: Skin hue angle; 4: Skin thickness (%); 5: Firmness (Kg cm^{-2}); 6: pH; 7: Titratable acidity (mg citric acid 100 g^{-1} DW); 8: Dry matter (%); 9: Ascorbic Acid (mg 100 g^{-1} DW); 10: Total phenolics (mg GAE 100 g^{-1} DW); 11: Antioxidant activity (% DPPH reduction).

Table 5. Physico-chemical and nutritional quality of early potatoes as affected by 'cultivation system × genotype' interaction.

Cultivation System	**Genotype**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Conventional											
	Arinda	59.3 b	23.3 b	83.6 b	6.4 cd	2.24 bc	193 ab	16.9 e	130 a	140 f	60 ab
	Bionica	59.4 b	24.2 ab	86.6 ab	6.4 cd	2.37 b	207 ab	18.0 d	134 a	209 e	73 a
	Ditta	59.1 b	28.5 a	87.4 ab	7.7 ad	2.21 bc	191 ab	18.3 cd	112 ab	291 cd	49 bc
	ISCI 4F88	65.4 a	27.7 a	89.7 a	6.5 cd	2.32 bc	225 a	20.2 b	90 bd	300 cd	48 bc
	Marabel	60.4 b	23.5 b	86.7 ab	6.0 d	1.83 d	177 bc	18.7 cd	49 e	163f	38 c
Organic											
	Arinda	61.1 ab	26.3 ab	86.4 ab	8.9 a	2.43 b	136 c	19.0 cd	97 bc	218 e	47 bc
	Bionica	65.1 a	25.9 ab	89.2 a	8.0 ac	2.17 bc	171 bc	18.6 cd	74 ce	324 c	46 bc
	Ditta	66.6 a	27.8 a	90.6 a	7.6 ad	2.03 cd	137 c	19.8 bc	82 bd	396 b	40 bc
	ISCI 4F88	65.1 a	27.5 a	89.3 a	8.4 ab	2.86 a	169 bc	21.5 a	66 de	451 a	35 c
	Marabel	63.2 ab	25.9 ab	85.8 ab	7.2 bd	2.15 bc	168 bc	18.9 cd	63 de	275 cd	32 c

Different letters within each column indicate significance at Fisher's protected LSD test ($p < 0.05$). 1: Skin lightness; 2: Skin chroma; 3: Skin hue angle; 4: Skin thickness (%); 5: Firmness (Kg cm^{-2}); 6: Titratable acidity (mg citric acid 100 g^{-1} DW); 7: Dry matter (%); 8: Ascorbic Acid (mg 100 g^{-1} DW); 9: Total phenolics (mg GAE 100 g^{-1} DW); 10: Antioxidant activity (% DPPH reduction).

Table 6. Physico-chemical and nutritional quality of early potatoes as affected by 'cultivation system × season' interaction.

Cultivation System	Season	Lightness	Chroma	Skin Thickness [1]	Ascorbic Acid [2]	Total Phenolics [3]	Antioxidant Activity [4]
Conventional	I	61.5 b	26.8 ab	6.8 c	96 b	267 b	45 b
	II	59.9 b	24.1 b	6.4 c	110 a	175 c	67 a
Organic	I	63.4 ab	25.4 ab	9.4 a	80 c	358 a	38 c
	II	65.0 a	27.9 a	7.7 b	73 d	308 b	47 b

Different letters within each column indicate significance at Fisher's protected LSD test ($p < 0.05$). [1] (%); [2] (mg 100 g^{-1} DW); [3] (mg GAE 100 g^{-1} DW); [4] (% DPPH reduction).

Irrespective of cultivar and season, **Org** tubers in comparison to conventional ones showed greater skin thickness (8.0 vs. 6.6% skin weight out of total tuber weight) (Table 4) in agreement with Haase et al. [28] and higher firmness (2.32 vs. 2.19 kg cm^{-2}) in agreement with that reported by Gilsenan [29].

This is attributable to a significantly lower maturity in **Con** tubers compared to **Org**, due to the higher N availability which may be held responsible for postponing maturity [29]. Although the total amount of nitrogen, phosphorus, and potassium applied as organic or mineral fertilizer was similar from a theoretical point of view, the actual availability of nutrients, even if not measured directly in our experiment, was presumably higher in **Con** compared to **Org**. In many studies conducted over several years using similar rates of NPK [7,14,19], the yield gap between organic and conventional production systems was mainly caused by differences in nutrient availability, especially nitrogen. High skin thickness and firmness found in **Org** tubers could prove very beneficial for early potatoes since they may reduce damage during harvesting, post-harvest handling, and transport.

Arinda, Bionica, and ISCI 4F88 showed in **Org** the greatest increase in skin thickness compared to **Con**; in the same cultivation system, a firmness increase was recorded both in ISCI 4F88 and Marabel (Table 5). The effects of the **Org** system on skin thickness were more evident in season I than in season II, attributable to the lower minimum temperatures recorded during the first season, which delayed maturation and, therefore, the thickening of the skin. **Org** tubers showed a slight reduction in pH to compared **Con** tubers in agreement with results of Gilsenan [29], who did not find any significant difference between them, and a marked reduction in titratable acidity (156 vs. 199 mg citric acid 100 g^{-1} DW). The most marked decrease in titratable acidity in **Org** compared to **Con** was found in Arinda, Ditta, and ISCI4F88; Marabel was the only genotype in which citric acid did not undergo significant variations due to the cultivation system (Table 5). Similar values for citric acid are reported in raw potatoes from crops grown in Mediterranean climate conditions [30].

3.2. Nutritional Traits

Dry matter is recognized as an important trait in the context of cooking quality, and it depends on the cultivar, climatic conditions, and agronomical practices [2]. Here we showed that, regardless of genotype and season, tuber dry matter content was higher under **Org-** than in **Con**-grown tubers (Table 4), which are in agreement with the results of other authors [7,13,31]. The higher N available in **Con** cultivation system presumably increases the size of the canopy during the early growth phase of the potato, which in turn diverts dry matter into the production of excess leaves and stem to the detriment of the tuber [32].

Arinda, Ditta, and ISCI 4F88 were more efficient under **Org** than in **Con** for improving tuber dry matter content, whereas the dry matter content of Marabel was unaffected by the cultivation system (Table 5). Bionica showed a small increase in tuber dry matter passing from the **Con** to **Org** system, which could be attributed to a reduction under Org in the 'planting-crop maturity' period which, as is known, particularly negative for late cultivars such as Bionica.

Regardless of genotype and season, ascorbic acid was greater in the **Con** tubers than in the **Org** ones, these results are in agreement with other studies on potato [13,15] and on other species [33–35]. Synthetic fertilizers employed in the **Con** cultivation system offer large quantities of bioavailable sources of nitrogen, which accelerates the plant development, allocating plant resources to growth purposes and, thus, enhancing the photosynthetic rate and, therefore, the production of the sugars needed for vitamin C synthesis. Organic fertilizers are less concentrated nutrient sources than conventional fertilizers. Moreover, some of them are characterized by low mineralization rates leading to lower nutrient bioavailability, in particular of nitrogen in coincidence with nutrient-demanding phenological stages [36]. Because potatoes are important sources of ascorbic acid [37], lower concentrations of this compound due to organic farming may decrease the nutritional value of potatoes with respect to vitamin C in the human diet. In addition, low ascorbic acid and citric acid concentration may reduce the tuber quality, as there is a higher risk of enzymatic browning and non-enzymatic gray discoloration after cooking; moreover, lower concentrations of citric and ascorbic acid at the same time could improve quality aspects related to taste [38]. The decrease in ascorbic acid in **Org** potatoes compared to **Con** was approximately 27% in Arinda, Ditta, and ISCI 4F88, whereas it was particularly evident in Bionica (approximately 45%) (Table 5). Arinda, Ditta, and ISCI are characterized by similar earliness which allows them to use the N available in **Org** well for growth purposes and synthesizing (or producing) ascorbic acid. On the contrary, Bionica, which is a later cultivar than the above-mentioned cultivars, fails to manage the little available N since it would need a longer ripening period than that of **Org** which is perhaps shortened due to biotic and abiotic stresses [12]. Marabel was the only cultivar that showed in **Org** a higher ascorbic acid content than in **Con**, according to the results of Brandt et al. [39]. Ascorbic acid decrease in **Org** was more marked in season II compared to season I (−34 vs. −17%) (Table 6), attributable to lower temperatures in season II which could have affected the synthesis of ascorbic acid. It is conceivable that the lower temperatures during season II could have decreased the mineralization processes in soil, leading to lower availability of nitrogen to the crop, which is linked to the synthesis of ascorbic acid. Total phenolics, regardless of other factors, showed greater values under **Org** compared to **Con** (333 vs. 221 mg GAE 100 g^{-1} DW) (Table 4). This result is in agreement with what has already been observed in potato [13,15,18] and other crops [40,41]. Some authors have suggested that the lower protection effectiveness of pesticides would result initially in higher rates of attack by pests and pathogens in organic plants compared with corresponding conventional ones, triggering the formation of induced defense compounds, which then subsequently protect the plant against diseases or pests [42,43]. This advantage was genotype-dependent and season-dependent. In particular, the maximum variation between cultivation systems (about 69%) was found in Marabel, the minimum (about 32%) in ISCI4F88, and intermediate (about 55%) in Arinda, Bionica, and Ditta (Table 5). It should be noted that both in **Con** and **Org**, Ditta and ISCI4F88 showed the highest values of total phenolic contents, 291 and 396 mg GAE 100 g^{-1} DW (Ditta) and 300 and 451 mg GAE 100 g^{-1} DW (ISCI4F88), respectively (Table 5). Presumably, both genotypes possess natural defenses, such as phenolic compounds [41], being that Ditta is a cultivar widely used by organic farmers in Europe and ISCI 4F88 is a new genotype created to be suitable for organic farming. The increase in total phenolics due to **Org** cultivation compared to **Con** in season II was double that of season I (+76 vs. + 34%) (Table 6). In season II plants were exposed to lower temperatures, which represents a stressful situation for organic farming systems, leading to the enhancement of natural defense substances, such as phenolic compounds [42,43]. As the majority of nutritional traits were largely affected by climatic conditions, it suggests the need for further investigations in different soil environments for several years.

Antioxidant activity, which represents a measure of the capacity of food extract to inhibit or delay oxidative processes was, regardless of genotype and season, greater in the **Con** tubers than in the **Org** ones (Table 4); the decrease in **Org** potatoes compared to **Con** was particularly evident in Bionica (about 37%) and intermediate in Arinda e ISCI4F88 (about 24%), whereas in Ditta and Marabel antioxidant capacity underwent a variation of approximately 17% (Table 5). Similar behaviour of antioxidant activity to that of ascorbic acid seems to confirm the important contribution of ascorbic acid to the antioxidant pattern in potato [21].

3.3. Sensorial Traits

Sensory traits of boiled tubers (consistency, typical taste, and after cooking blackening) were significantly influenced only by genotype (Table 7); the data are in agreement with that reported for the boiled tubers from the main potato crop [8,44] and early crop [13]. Boiled tubers from both **Con** and **Org** cultivation systems had a hard consistency and they were not blackened after cooking. In our trial, Ditta and Marabel were well-suited to boiling thanks to their moderate hard consistency and delicate taste (Table 6).

Table 7. Sensory traits after boiling and frying of early potatoes as affected by the main factors.

	After Boiling			After Frying		
	Consistency [1]	Typical Taste [2]	Blackening [3]	Crispness [2]	Typical Taste [2]	Browning Index [4]
Cultivation System						
Conventional	2.0 a	2.3 a	0	1.8 b	2.3 b	2.3 a
Organic	2.1 a	2.5 a	0	2.3 a	2.5 a	2.1 b
Genotype						
Arinda	1.4 c	2.7 a	0	2.2 b	2.6 a	2.1 c
Bionica	2.0 b	2.7 a	0	1.4 d	2.4 b	2.6 a
Ditta	2.7 a	2.3 bc	0	1.8 c	2.3 bc	2.3 b
ISCI 4F88	1.5 c	2.0 c	0	2.9 a	2.3 bc	2.0 c
Marabel	2.4 a	2.4 ab	0	2.0 b	2.2 c	1.9 c
Season						
Season I	1.9 b	2.5 a	0	2.2 a	2.6 a	2.0 b
Season II	2.2 a	2.3 a	0	1.9 b	2.1 b	2.3 a

Different letters within each column's factor indicate significance at Fisher's protected LSD test ($p < 0.05$);[1] from 1 = very tender to 5 = very hard; [2] from 1= absent to 5= very pronounced; [3] from 0 = absence of the phenomenon to 2 = widespread blackening; [4] from 0 = extra white to 6 = complete browning.

Sensory traits of fries (crispness, taste, browning) were significantly influenced by the cultivation system, genotype, and their interaction. **Org** cultivation compared to **Con** improved sensory performance of fried tubers, with higher crispness, typical taste, and lower browning index (Table 7).

It is expected that organic cultivation with variation in the available nitrogen for plants, and consequently in tuber dry matter content and the sugar content of tubers, will influence these characteristics [12]. Regardless of the cultivation system, lower crispness and typical taste after frying was found in season II compared to season I, attributable to the lower dry matter content of tubers recorded in season II (Table 6). **Org** cultivation particularly improved crispness and typical taste after frying in Arinda, Ditta, and ISCI 4F88 and browning index in Bionica (Table 8).

Table 8. Sensory traits after frying of early potatoes as affected by 'cultivation system × genotype' interaction.

Cultivation System	Genotype	Crispness [1]	Typical Taste [1]	Browning Index [2]
Conventional	Arinda	1.8 d	2.4 ab	2.2 bc
	Bionica	1.4 e	2.7 a	2.9 a
	Ditta	1.4 e	1.8 d	2.5 ab
	ISCI 4F88	2.4 b	2.3 bc	2.0 c
	Marabel	2.3 bc	2.0 c	2.0 c
Organic	Arinda	2.3 bc	2.7 a	2.0 c
	Bionica	1.4 e	2.3 bc	2.3 bc
	Ditta	2.3 bc	2.7 a	2.2 bc
	ISCI 4F88	3.3 a	2.4 ab	2.1 bc
	Marabel	2.0 cd	2.3 bc	1.8 c

Different letters within each column indicate significance at Fisher's protected LSD test ($p < 0.05$). [1] from 1 = absent to 5 = very pronounced; [2] from 0 = extra white to 6 = complete browning.

4. Conclusions

Overall, considerable differences were found between organically- and conventionally-grown "early" potato tubers relative to their physico-chemical, nutritional, and sensory traits. Organically-grown potatoes in comparison to conventional ones showed better appearance, due to more brilliant and intense skin color, as well as greater skin thickness, firmness, total phenolics and dry matter content, and better sensory attributes (crispness, typical taste, and browning degree) after frying. However, organic cultivation compared to conventional significantly decreased ascorbic acid content and antioxidant activity and did not affect sensorial traits after boiling, highlighting that the superiority of organic potatoes does not concern all aspects of quality. The quality of the tuber was also under genetic control: Arinda, Ditta, and ISCI4F88 were the cultivars that recorded the best performance under the organic cultivation system. In particular, the Italian breeding clone ISCI 4F88 compared to the cultivar Ditta, a very popular choice for organic potato growers in Europe, showed higher total phenolics content under organic cultivation, which could be of interest for their health-promoting properties. The qualitative differences between organically- and conventionally-grown tubers were largely influenced by seasonal conditions, suggesting the need for further investigations into this effect. Even if the response of organic cultivation on overall quality characteristics also depended upon seasonal conditions, genotype choice plays a key role in optimizing this production system, highlighting the importance of breeding programs for organic agriculture.

Author Contributions: Conceptualization, A.I.; methodology, A.I., M.G.M. and B.P.; validation, A.I.; formal analysis, A.I. and M.G.M.; investigation, A.I., M.G.M. and B.P.; resources, B.P.; data curation, M.G.M.; writing—original draft preparation, A.I.; writing—review and editing, A.I. and M.G.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data for this study has been included in the tables.

Acknowledgments: The authors are grateful to Salvatore Scandurra for technical assistance.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. FAO Food and Agricultural Organization. 2019. Available online: www.fao.org (accessed on 23 March 2021).
2. Ierna, A.; Rizzarelli, P.; Malvuccio, A.; Rapisarda, M. Effect of different anti-browning agents on quality of minimally processed early potatoes packaged on a compostable film. *LWT-Food Sci. Technol.* **2017**, *85*, 434–439. [CrossRef]
3. Ierna, A.; Melilli, M.G. Ascorbic Acid and Total Phenolics Content in Early Potatoes as Affected by Growing Season, Genotype and Harvest Time. *Acta Hortic.* **2014**, 133–141. [CrossRef]
4. Friedman, M. Chemistry, Biochemistry, and Dietary Role of Potato Polyphenols. A Review. *J. Agric. Food Chem.* **1997**, *45*, 1523–1540. [CrossRef]
5. Ierna, A.; Mauromicale, G. Sustainable and Profitable Nitrogen Fertilization Management of Potato. *Agronomy* **2019**, *9*, 582. [CrossRef]
6. Bacchi, M.A.; De Nadai Fernandes, E.A.; Tsai, S.M.; Santos, L.G.C. Conventional and organic potatoes: Assessment of elemental composition using k 0 -INAA. *J. Radioanal. Nucl. Chem.* **2004**, *259*, 421–424. [CrossRef]
7. Maggio, A.; Carillo, P.; Bulmetti, G.S.; Fuggi, A.; Barbieri, G.; De Pascale, S. Potato yield and metabolic profiling under conventional and organic farming. *Eur. J. Agron.* **2008**, *28*, 343–350. [CrossRef]
8. Woese, K.; Lange, D.; Boess, C.; Bögl, K.W. A Comparison of Organically and Conventionally Grown Foods—Results of a Review of the Relevant Literature. *J. Sci. Food Agric.* **1997**, *74*, 281–293. [CrossRef]
9. Ierna, A. Characterization of potato genotypes by chlorophyll fluorescence during plant aging in a Mediterranean environment. *Photosynthetica* **2007**, *45*, 568–575. [CrossRef]
10. Ierna, A.; Mauromicale, G. How Moderate Water Stress Can Affect Water Use Efficiency Indices in Potato. *Agronomy* **2020**, *10*, 1034. [CrossRef]
11. Ierna, A. Tuber yield and quality characteristics of potatoes for off-season crops in a Mediterranean environment. *J. Sci. Food Agric.* **2010**, *90*, 85–90. [CrossRef]

12. Ierna, A.; Parisi, B. Crop growth and tuber yield of "early" potato crop under organic and conventional farming. *Sci. Hortic. (Amsterdam)* **2014**, *165*, 260–265. [CrossRef]
13. Lombardo, S.; Pandino, G.; Mauromicale, G. Nutritional and sensory characteristics of "early" potato cultivars under organic and conventional cultivation systems. *Food Chem.* **2012**, *133*, 1249–1254. [CrossRef]
14. Lombardo, S.; Lo Monaco, A.; Pandino, G.; Parisi, B.; Mauromicale, G. The phenology, yield and tuber composition of 'early' crop potatoes: A comparison between organic and conventional cultivation systems. *Renew. Agric. Food Syst.* **2013**, *28*, 50–58. [CrossRef]
15. Lombardo, S.; Pandino, G.; Mauromicale, G. The effect on tuber quality of an organic versus a conventional cultivation system in the early crop potato. *J. Food Compos. Anal.* **2017**, *62*, 189–196. [CrossRef]
16. Fernqvist, F.; Spendrup, S.; Ekelund, L. Changing consumer intake of potato, a focus group study. *Br. Food J.* **2015**, *117*, 210–221. [CrossRef]
17. Wszelaki, A.L.; Delwiche, J.F.; Walker, S.D.; Liggett, R.E.; Scheerens, J.C.; Kleinhenz, M.D. Sensory quality and mineral and glycoalkaloid concentrations in organically and conventionally grown redskin potatoes (*Solanum tuberosum*). *J. Sci. Food Agric.* **2005**, *85*, 720–726. [CrossRef]
18. Hajŝlová, J.; Schulzová, V.; Slanina, P.; Janné, K.; Hellenäs, K.E.; Andersson, C. Quality of organically and conventionally grown potatoes: Four-year study of micronutrients, metals, secondary metabolites, enzymic browning and organoleptic properties. *Food Addit. Contam.* **2005**, *22*, 514–534. [CrossRef]
19. Djaman, K.; Sanogo, S.; Koudahe, K.; Allen, S.; Saibou, A.; Essah, S. Characteristics of organically grown compared to conventionally grown potato and the processed products: A review. *Sustainability* **2021**, *13*, 6289. [CrossRef]
20. Violante, P. *Metodi di Analisi Chimica del Suolo*; Franco, A., Ed.; Italian Ministry of Agriculture: Milan, Italy, 2000.
21. Ierna, A.; Pellegrino, A.; Di Silvestro, I.; Buccheri, M. Sensory and physico-chemical characteristics of minimally processed "early" potato tubers as affected by anti-browning treatments and cultivar. *Acta Hortic.* **2016**, *1141*, 229–236. [CrossRef]
22. Hunter, R.S.; Harold, R.W. *Uniform Color Scale. The Measurement of Appearance*, 2nd ed.; John Wiley and Sons Inc.: New York, NY, USA, 1987; Chapter 8.
23. McGuire, R.G. Reporting of Objective Color Measurements. *HortScience* **2019**, *27*, 1254–1255. [CrossRef]
24. AOAC. *Official Methods of Analysis of the AOAC*; AOAC: Rockville, MD, USA, 2008.
25. Slinkard, K.; Singleton, V.L. Total Phenol Analysis: Automation and Comparison with Manual Methods. *Am. J. Enol. Vitic.* **1977**, *28*, 49–55.
26. Brand-Williams, W.; Cuvelier, M.E.; Berset, C. Use of a free radical method to evaluate antioxidant activity. *LWT-Food Sci. Technol.* **1995**, *28*, 25–30. [CrossRef]
27. Hejtmánková, K.; Kotíková, Z.; Hamouz, K.; Pivec, V.; Vacek, J.; Lachman, J. Influence of flesh colour, year and growing area on carotenoid and anthocyanin content in potato tubers. *J. Food Compos. Anal.* **2013**, *32*, 20–27. [CrossRef]
28. Haase, T.; Schüler, C.; Haase, N.U.; Heß, J. Suitability of Organic Potatoes for Industrial Processing: Effect of Agronomical Measures on Selected Quality Parameters at Harvest and after Storage. *Potato Res.* **2007**, *50*, 115–141. [CrossRef]
29. Gilsenan, C.; Burke, R.M.; Barry-Ryan, C. A study of the physicochemical and sensory properties of organic and conventional potatoes (Solanum tuberosum) before and after baking. *Int. J. Food Sci. Technol.* **2010**, *45*, 475–481. [CrossRef]
30. Finotti, E.; Bertone, A.; Vivanti, V. Balance between nutrients and anti-nutrients in nine Italian potato cultivars. *Food Chem.* **2006**, *99*, 698–701. [CrossRef]
31. Herencia, J.F.; García-Galavís, P.A.; Dorado, J.A.R.; Maqueda, C. Comparison of nutritional quality of the crops grown in an organic and conventional fertilized soil. *Sci. Hortic. (Amst.)* **2011**, *129*, 882–888. [CrossRef]
32. Tein, B.; Kauer, K.; Eremeev, V.; Luik, A.; Selge, A.; Loit, E. Farming systems affect potato (*Solanum tuberosum* L.) tuber and soil quality. *F. Crop. Res.* **2014**, *156*, 1–11. [CrossRef]
33. Bender, I.; Ess, M.W.V.; Matt, D.; Moor, U.; Tr nutare, T.N.; Luik, A. Quality of organic and conventional carrots. *Agron. Res.* **2009**, *7*, 572–577.
34. Pieper, J.R.; Barrett, D.M. Effects of organic and conventional production systems on quality and nutritional parameters of processing tomatoes. *J. Sci. Food Agric.* **2009**, *89*, 177–194. [CrossRef]
35. Toor, R.K.; Savage, G.P.; Heeb, A. Influence of different types of fertilisers on the major antioxidant components of tomatoes. *J. Food Compos. Anal.* **2006**, *19*, 20–27. [CrossRef]
36. Palmer, M.W.; Cooper, J.; Tétard-Jones, C.; Średnicka-Tober, D.; Barański, M.; Eyre, M.; Shotton, P.N.; Volakakis, N.; Cakmak, I.; Ozturk, L.; et al. The influence of organic and conventional fertilisation and crop protection practices, preceding crop, harvest year and weather conditions on yield and quality of potato (Solanum tuberosum) in a long-term management trial. *Eur. J. Agron.* **2013**, *49*, 83–92. [CrossRef]
37. Brown, C.R. Antioxidants in potato. *Am. J. Potato Res.* **2005**, *82*, 163–172. [CrossRef]
38. Silva, G.H.; Chase, R.W.; Hammerschmidt, R.; Cash, J.N. After-Cooking Darkening of Spartan Pearl Potatoes as Influenced by Location, Phenolic Acids, and Citric Acid. *J. Agric. Food Chem.* **1991**, *39*, 871–873. [CrossRef]
39. Brandt, K.; Leifert, C.; Sanderson, R.; Seal, C.J. Agroecosystem Management and Nutritional Quality of Plant Foods: The Case of Organic Fruits and Vegetables. *CRC. Crit. Rev. Plant Sci.* **2011**, *30*, 177–197. [CrossRef]
40. Zapata, P.J.; Tucker, G.A.; Valero, D.; Serrano, M. Quality parameters and antioxidant properties in organic and conventionally grown broccoli after pre-storage hot water treatment. *J. Sci. Food Agric.* **2013**, *93*, 1140–1146. [CrossRef]

41. Chassy, A.W.; Bui, L.; Renaud, E.N.C.; Van Horn, M.; Mitchell, A.E. Three-Year Comparison of the Content of Antioxidant Microconstituents and Several Quality Characteristics in Organic and Conventionally Managed Tomatoes and Bell Peppers. *J. Agric. Food Chem.* **2006**, *54*, 8244–8252. [CrossRef]
42. Winter, C.K.; Davis, S.F. Organic Foods. *J. Food Sci.* **2006**, *71*, R117–R124. [CrossRef]
43. Wegener, C.B.; Jansen, G.; Jurgens, H.-U. Influence of Drought and Wounding Stress on Soluble Phenols and Proteins in Potato Tubers. *Sustain. Agric. Res.* **2014**, *3*, 1. [CrossRef]
44. Brazinskiene, V.; Asakaviciute, R.; Miezeliene, A.; Alencikiene, G.; Ivanauskas, L.; Jakstas, V.; Viskelis, P.; Razukas, A. Effect of farming systems on the yield, quality parameters and sensory properties of conventionally and organically grown potato (*Solanum tuberosum* L.) tubers. *Food Chem.* **2014**, *145*, 903–909. [CrossRef]