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Effects of Organic and Conventional Cultivation on Composition and Characterization of Two Citrus Varieties 'Navelina' Orange and 'Clemenules' Mandarin Fruits in a Long-Term Study

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Abstract: A transition towards an organic food system is taking place around the world. This process is favored by growing consumer demand, who associate organic crops with being healthier, tastier, and safer for the environment than conventional crops. Citrus is one of the most widely produced crops worldwide and has important socio-economic and cultural significance in the Mediterranean area. The aim of this work is twofold; on the one hand, it reveals the variability of a set of physical–chemical and nutritional quality parameters of two citrus fruit varieties, 'Navelina' oranges and 'Clemenules' mandarins, from organic and conventional production in a long-term study. On the other hand, taking advantage of the large number of results, a model is proposed that allows the successful differentiation of citrus fruits from organic and conventional production and a tool that allows predicting the production system of citrus fruits. The results suggest that organically produced citrus fruits do not generate differences in terms of external aspects, providing fruits that are acceptable to the market. Organic production techniques influenced the lower peel content and higher pulp and juice content in 'Navelina' orange and 'Clemenules' mandarin fruits and led to a greater ability to synthesize vitamin C in the juice, more essential oils in the skin, and higher seed numbers, although in all cases, the fruits can be classified as having low seed numbers. Two discriminating equations were obtained that use easy-to-measure parameters to successfully classify organic citrus fruits. The classification and prediction models obtained constitute useful tools to help in the control of the purity/authenticity of organic citrus fruits.

Keywords: vitamin C; citrus; comparison; Mediterranean conditions; physicochemical quality; nutritional

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1. Introduction

Citrus fruits (*Citrus* L. from Rutaceae) are among the major fruit crops in international trade in terms of economic value and are in high demand worldwide for fresh consumption, juice production, the manufacture of goods such as jams and frozen concentrates, and as food additives for dishes and beverages [1,2]. In addition, citrus fruits are also widely used to produce essential oils and for the manufacture of liqueurs [3]. Annual citrus production is 158 million tons, with a cultivation area of more than 10.1 million hectares worldwide [4]. Citrus production has important economic, social, and cultural significance in the Mediterranean region; in fact, oranges are one of the largest agricultural export crops. Citrus orchards are especially important near Valencia, where they produce more than 70% of the total Spanish citrus crops [5].

The *Citrus* genus includes oranges, lemons, grapefruits, limes, mandarins, kumquats, tangelos, and others [6]. They represent an important part of our daily diet, not only due to their attractive colors, special aromas, and delicious flavors, but also their high nutritional value and health-promoting effects [7,8]. Evidence from several in vitro and in vivo studies has related citrus fruit consumption to a reduced risk of chronic diseases such as cancers, cardiovascular diseases, and diabetes [8,9]. These fruits contain a range of highly beneficial bioactive compounds, such as polyphenols, coumarins, limonoids, carotenoids, essential oils, minerals, and vitamins, which alone or in combination show antimicrobial and antioxidant properties and help boost the body's immune system [7,10–13]. Due to their high vitamin C concentration and the large per capita consumption volume, citrus fruits are an important source of ascorbic acid in the human diet [14,15]. As the main antioxidant compound, vitamin C concentration is an important nutritional quality indicator of citrus fruit and its derivative products. The current recommended daily allowance (RDA) for this vitamin intake is 80–95 mg/day to have a positive effect on the organism.

The nutritional value of food depends on many environmental factors, such as soil type, fertilization practices, and production system (organic vs. conventional farming), among others. Nowadays, environmentally friendly farming practices are essential to ensure future production. This is a current topic that has attracted public interest and has generated much discussion [16]. Conventional farming systems have focused mainly on yield rather than on the sustainable use of available resources [17]. Technological advances and economies of scale encouraged the use of chemical solutions to control pests and diseases and increase soil productivity [10]. The massive use of chemically synthesized fertilizers, heavy machinery, and intensive agricultural practices contribute to high greenhouse gas emissions [18]. In addition, these practices have led to a rapid decline in biodiversity, affecting important ecosystem functions, such as the regulation of herbivore populations by their natural enemies, plant pollination by insects, or the decomposition process of soil fauna, resulting in significant imbalances [19].

Nowadays, agriculture and the food industry are facing new trends in the development of organic farming practices [20,21]. These techniques offer an alternative to industrial farming and are favored by the growing consumer demand for organic fruit and vegetables [22]. This is because consumers associate organic products with healthier and tastier food and consider organic food to be more environmentally friendly than their conventionally grown counterparts [23]. One of the serious problems in the production of citrus fruits is the intensification of cultivation carried out in conventional systems, generating pollution mainly derived from the nitrogen fertilizers used on orange farms, which have caused many Spanish citrus-growing areas to have nitrate levels in their aquifers above the legal limit, exceeding 300 ppm in large areas, as well as concentrations of pesticides in drinking water [24,25].

Currently, an organic transition is taking place in agricultural soil management for citrus orchards [26]. Organic farming seeks solutions to avoid soil degradation and increase soil quality. Cerda et al. [27] reported that plant covers (crops and weeds) are valid measures to control extreme soil losses. Concerns for the environment, the welfare of future generations, the aspiration to produce high-quality products, higher economic profitability, and the will to reduce dependence on agrochemicals encourage citrus farmers in the Valencia Region toward the organic transition [28]. Most well-designed studies reported that organic farming has the potential to produce high-quality food, with some relevant increases in terms of health-promoting phytonutrients and certain vitamins and minerals, and lower levels of pesticide residues, which could be assumed to provide health benefits [29]. It has long been known that there is a clear link between the food we eat and our health [30]. Citrus-rich diets have been strongly associated with numerous health benefits and a reduced risk of disease [31].

The recent studies on the effects of applying organic methods in citrus crops focus on the impacts on the soil [32] and other environmental effects [33]; few papers study the effect on the quality of the fruits. Some previous work [34] found significantly higher vitamin C levels in red oranges and other fruits grown in organic conditions [35]. Recently, He et al. [36] indicated that the application of organic substance fertilizers, such as humic and fulvic acids, improved the quality of 'Eureka' lemon fruits. In particular, the edible rate and juice production increased, as well as the contents of vitamin C, total acid, total sugar, total soluble solids, and the number of seeds.

The objective of this study is twofold; on the one hand, it reveals the variability of a set of physical–chemical and nutritional quality parameters of two citrus fruit varieties, 'Navelina' oranges (*Citrus sinensis* L. Osbeck) and 'Clemenules' mandarins (*Citrus reticulata* Blanco), from organic and conventional production in a long-term study. On the other hand, taking advantage of the large number of results, a model is proposed that allows the successful differentiation of citrus fruits from organic and conventional production.

This study will contribute to increasing the knowledge of the effect of the organic production method on citrus fruit quality. It will also provide a prediction complex for classifying citrus fruits according to the production system (organic and conventional).

2. Materials and Methods

2.1. Experimental Materials

The fruits were grown in the Valencia area, based on two production systems (organic and conventional) and different production years. Several fruit quality parameters were analyzed, including physical (shape, fresh weight, diameter, height, peel color index, percentage of juice, peel, pulp, number of seeds, juice density, skin thickness, and albedo thickness) and chemical (total soluble solids, pH, total acidity, ripeness index, essential oil, and vitamin C concentration) characteristics. All parameters are related to quality and organoleptic attributes.

Fruits of the mandarin variety 'Clemenules' (a natural bud mutation of the variety Fina) and 'Navelina' orange were used as the plant material. The citrus fruits were harvested at their optimum ripening stage in the period between November and January during seven different seasons (1999–2000, 2001–2002, 2007–2008, 2008–2009, 2009–2010, 2010–2011, and 2020–2021). It was not possible to analyze fruits from all consecutive seasons since 1999, mainly due to resource problems and climatic conditions. However, there are a large number of study years that include possible seasonal variability. Plants were grown in the Central-East of the Valencian Community, in the province of Valencia, under open field conditions, both in organic (ORG) and conventional (CONV) systems, with similar edaphoclimatic and environmental conditions. The citrus plots are located inland, approximately 30 km from the Mediterranean coast, in an area known as La Casella (Ribera Alta region). With a semi-arid Mediterranean climate, the average annual temperature is 17.6 °C (July is the warmest month of the year, with average temperatures of 26.4 °C, and January is the coldest month, with average temperatures of 9.8 °C). The driest month is July, with 9 mm of precipitation, and most precipitation falls in October (63 mm); the annual accumulated rainfall is 460 mm.

The type of soil in the study area is 'entisols' [37]. In general, these soils are characterized by a loamy clay texture, and the main composition (10–30 cm deep) properties of organic and conventional soils are shown in Table 1. In general, organic soils are characterized by having a higher water content, higher organic matter content, higher enzymatic activity, and higher cation exchange capacity, due to the higher concentrations of calcium, potassium, and magnesium.

2.2. Experimental Method

The fruits were harvested in situ in the plots of origin, from healthy and mature trees that were initially older than 20 years. The variety 'Navelina' was grafted on Citrange troyer, on Citrange carrizo, and on bitter orange trees, depending on the plot. The variety 'Clemenules' was grafted on Citrange troyer, Citrange carrizo rootstock, particularly with loamy soils and drip irrigation systems. Organic farms are certified according to European regulations, specifically EEC Regulation 2092/91, Council Regulation (EC) 834/2007, and Regulation (EU) 2018/848 of the European Parliament and the Council. As it is a long-term study, the organic citrus plots have gone through different regulatory changes in the European Union, but the changes in regulations have not affected the traditional management systems that have been in place for more than twenty years.

Table 1. Composition characteristics of organic and conventional soils.

Parameter	Organic Soil	Conventional Soil
Humidity (%)	7.00 ± 0.23	5.88 ± 0.29
pH	7.75 ± 0.04	7.08 ± 0.05
Conductivity (dS m^{-1})	0.160 ± 0.006	0.122 ± 0.009
$CaCO_3$ (%)	1.79 ± 0.09	0.92 ± 0.06
Total N (%)	0.059 ± 0.005	0.041 ± 0.007
Organic matter (%)	1.28 ± 0.09	0.85 ± 0.27
C/N	12.92 ± 0.78	11.61 ± 2.13
Enzymatic activity * (μg PNP g^{-1} soil h^{-1})	186.15 ± 15.97	64.21 ± 10.47
K (mg kg^{-1})	113.74 ± 17.97	79.15 ± 10.58
P (mg kg^{-1})	54.93 ± 4.72	59.00 ± 1.81
Ca (mg kg^{-1})	1641.24 ± 153.39	664.20 ± 84.07
Mg (mg kg^{-1})	252.67 ± 28.62	149.20 ± 5.62
Na (mg kg^{-1})	51.57 ± 1.03	50.53 ± 0.37
Fe (mg kg^{-1})	5.85 ± 0.36	9.40 ± 0.44
Cu (mg kg^{-1})	0.71 ± 0.07	2.36 ± 0.43
Zn (mg kg^{-1})	3.81 ± 0.35	12.46 ± 1.79
Cation exchange capacity	10.78 ± 0.75	4.96 ± 0.48

* Determined as alkaline phosphatase (PNP = p-nitrophenol).

In all cases, five organic orchards and five conventional ones, located in the same production area, were sampled. The organic plots have live hedges in their perimeters that act as a natural border and as a refuge for auxiliary fauna. Organic soils have plant covers, mainly a mixture of vetch (100 kg ha^{-1}) and oats (80 kg ha^{-1}). Fertilization consisted of the contribution of between 15 and 20 tons of sheep manure per hectare and year; half was usually contributed at the beginning of September and the other half in March. Authorized biological control applications were made when the balance of the ecosystem was destabilized. The rest of the irrigation techniques and water doses, pruning, etc., were similar to conventional techniques. There are also no differences in the planting frames, with average densities of 6 m × 4 m. The conventional soils are characterized by not having vegetation covers (bare soils), using tillage and authorized herbicides. Conventional fertilization consisted of the application by hectare and year of 350 kg of nitrogen, 80 kg of P_2O_5, 140 kg of K_2O, and 180 kg of MgO, and applications of microelements, mainly 1 kg of iron, using inorganic sources of synthesis. Phytosanitary practices were carried out in the conventional plots when an imbalance occurred, using the authorized substances.

2.3. Sampling and Analytical Methodology

In each season, the harvesting was carried out manually, on the same day, taking fruits from the entire plot. Trees were randomly selected, eliminating those on the perimeter, and fruits were taken from inside and outside the canopy, from the four cardinal points. Approximately 100 kg of fruits per 1250 m^2 and year and from a whole experimental area were collected for analysis (15 sample trees).

The fruits were in a range of commercial ripeness recommended for local farmers, and this point varies from season to season depending on climatic parameters. In total, 1588 'Clemenules' fruits (794 ORG and 794 CONV) and 984 'Navelina' fruits (492 ORG and 492 CONV) were examined. The quality parameters analyzed for each fruit are presented in Figure 1. Each parameter analysis was performed in triplicate. The fresh citrus fruits studied were analyzed to assess their overall quality.

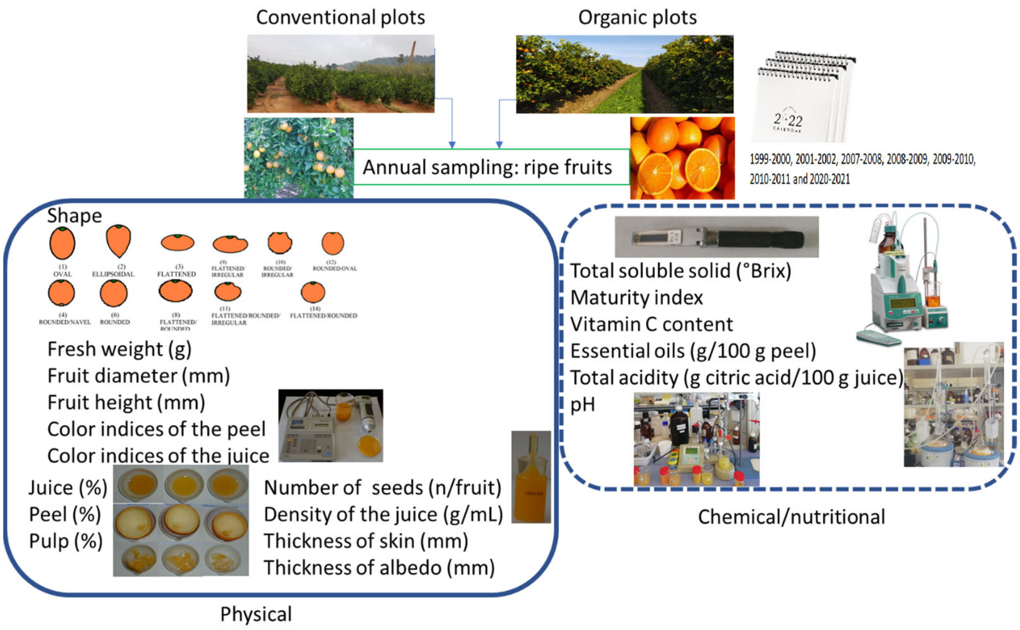

Figure 1. Scheme of several physical, chemical, and nutritional parameters evaluated for each fruit sample.

Representative fruits from each sample plot were individually weighed, measured, and used for juice extraction. The number of seeds was determined by counting the seeds extracted from the pulp of each fruit one by one. Fruit height (H), equatorial diameter (D), rind thickness (mm), skin thickness (ST), and albedo thickness (AT) were measured using a digital electronic slide gauge (model CD-15 DC; Mitutoyo (UK) Ltd., Telford, UK) within 0.01 mm accuracy. Weights of individual fruits (W), pulp, juice, and skin were obtained by weighing them on an analytical balance (CB-Junior, Cobos) with an accuracy of ±0.001 g; the content of pulp (P), skin (S), and juice (J) is expressed as a percentage. Peel color measurements in CieLab space were performed at two random points on the citrus skin and we averaged the values, and one point in the juice surface was measured using a colorimeter (Konica Minolta CR-300, Photo Imaging Inc., Mahwah, NJ, USA), obtaining the color components (L*, a*, b*), as well as the color index (CI) in skin and juice, which was calculated by the following equation: $CI = 1000 \times a/(L \times b)$, where L* indicates brightness, a* indicates chromaticity on a green (−) to red (+) axis, and b* indicates chromaticity on a blue (−) to yellow (+) axis; this index is widely used in the citrus industry as a maturation index [38].

Each fruit was manually squeezed and filtered to obtain juice, which was used to determine juice density (Dy) by the pycnometer method; total soluble solids content (TSS, °Brix) was determined by refractometry (method 932.12); and pH (method 981.12) and total acidity (TA) expressed in g anhydrous citric acid/100 mg juice (%) were determined (method 942.15) according to AOAC (1995) [39]. In addition, the TSS/TA ratio was calculated to define the ripeness index (RI) of citrus fruit [40]. Fruit shape was determined by visual observation, using a citrus chart, classifying them as oval, round, flattened, and ellipsoidal, according to a numerical scale ranging from 1 for an oval shape to 14 for a rounded/flattened shape. A frequency mosaic graph was used to identify the shape of the citrus fruit for the two varieties.

Vitamin C concentration (Vit C) in citrus juice was determined by potentiometric titration with chloramine-T, using automatic titration equipment (702 SM Titrino, Metrohm, Herisau, Switzerland) and expressed in mg ascorbic acid (AA) per 100 g of juice [41]. The essential oils are determined in the flavedo. The method applied for the determination of essential oil concentration (EOC) consisted of the extraction of these oils from citrus skin by the Clavenger system [42], and the results are expressed in g/100 g of peel (%).

2.4. Data Analysis

Data obtained were processed using Statgraphics® Centurion 18. For each citrus fruit variety, data were subjected to a two-factor analysis of variance (ANOVA) using a fixed effects model for cultivar season and production system. The significance of main effects and interactions was obtained from the ANOVA, and differences among main treatments and combinations were identified with Student–Newman–Keuls multiple-range tests. Discriminant analysis was also performed to classify the different observations. The main objective of the discriminant analysis was to calculate the linear combinations of the classifying fruits that maximize the difference between the production systems. Discriminant analysis was applied for explanatory and predictive purposes.

3. Results

3.1. Descriptive Results: Effect of Analysis of Variance

Tables 2 and 3 show the results of the physical and chemical quality parameters, respectively, of ‘Navelina’ fruit, produced by organic and conventional systems during the seven different seasons considered in the study. Tables 4 and 5 show the results of ‘Clemenules’ fruit for the same parameters. Some parameters were not analyzed in all the seasons due to the approach of the individual objectives in the corresponding season, but the existing data allow the statistical study to be carried out.

In the present study, the season had a significant influence on all physical and chemical quality parameters of ‘Navelina’ and ‘Clemenules’ fruits, except for the number of seeds for ‘Navelina’ fruits and skin thickness for ‘Clemenules’ fruits (Tables 2 and 4, respectively). This was mainly due to the influence of environmental factors, such as climatic conditions, rainfall frequency, air temperature, and daylight hours, among other factors. As reported by Lado et al. [43], climatic conditions are the most significant external factors affecting fruit quality. In general, the long-term study aims to minimize the effects of climatic incidences in favor of growing conditions. In this sense, shape, height, juice content, the number of seeds, juice color index, albedo thickness, total acidity, ripeness index, and vitamin C concentration in Navelina fruits are parameters that have the same behavior in all seasons; for example, for Navelina fruits, regardless of the season of the year, on average, the organic fruits had a higher total acidity value and contained a higher vitamin C content.

The significant differences detected in the physical quality parameters, for the cultivation system, in ‘Navelina’ fruit are CI of peel, skin, and pulp (%) (Table 2). Conventional oranges have a significantly higher peel color index and skin percentage (10.29 and 26.95%, respectively) than organic (9.97 and 25.17%, respectively), while the pulp percentage is significantly higher in organic ‘Navelina’ fruits (27.77%) than in conventional ones (26.05%).

Significant effects of cropping system x season are observed for several physical quality parameters: fresh weight, fruit diameter, skin CI, peel and pulp percentage, a* and b* (color parameters), and skin thickness (Table 2). In the parameters where no statistically significant interaction effects are observed, the farming system shows the same trend in all seasons.

For the chemical quality parameters of the ‘Navelina’ fruit samples, significant differences due to the cultivation system are observed for pH value, vitamin C concentration, and percentage of essential oils (Table 3). Organic ‘Navelina’ fruits had a significantly higher mean pH value (3.64) than conventional ‘Navelina’ fruits (3.58). Vitamin C concentration was significantly higher in ‘Navelina’ fruits grown under organic conditions with mean values of 63.70 mg per 100 g juice than their respective counterparts (57.51 mg per 100 g juice). Essential oil concentration was also significantly higher in organic ‘Navelina’ oranges (0.34 g per 100 g peel) than in conventional samples (0.28 g per 100 g peel). The growing method $\times$ season interaction significantly affects total soluble solids, pH, juice density, and essential oil content (Table 3). Organic ‘Navelina’ fruits showed a higher number of seeds per fruit (although in no case are values of the average number of seeds in fruits greater than 1) with differences to the limit to become significant (p-value = 0.0506).

Table 2. Physical quality characteristics of 'Navelina' fruits grown under organic (ORG) and conventional (CONV) conditions in the seven different seasons and probability (*p*-value) for the effects of cultivation method, season, and their interaction.

		Physical Quality Characteristics [2]												
Factors [1]		**Shape**	**W (g/Fruit)**	**D (mm)**	**H (mm)**	**Skin CI**	**J (%)**	**S (%)**	**P (%)**	**L***	**a***	**b***	**ST (mm)**	**AT (mm)**
Cultivation system	ORG	6.60	222.82	75.25	78.53	9.97	47.07	25.17	27.77	65.06	35.09	56.47	4.87	2.18
	CONV	6.74	229.66	75.50	79.62	10.29	46.86	26.95	26.05	64.66	35.12	56.38	5.04	2.37
	p-value	0.7275	0.0868	0.5733	0.4197	0.0322	0.7221	0.0001	0.0027	0.2419	0.8824	0.7983	0.2907	0.0707
Season	1999–2000	1.40	250.09	77.90	83.32	8.19	43.00	26.83	30.16	62.22	34.53	61.67	5.09	1.60
	2001–2002						42.55	27.42	29.56				4.27	1.35
	2007–2008		263.21	80.70	79.66	7.17	50.09	26.88	23.04	68.93	34.32	69.71	5.55	
	2008–2009		183.71	69.70	73.82	13.90	46.65	26.47	26.87	55.47	42.22	55.30		
	2009–2010		236.83	76.26	85.39	14.23	49.44	25.20	25.36	55.67	38.65	50.81		
	2010–2011		199.45	72.12	77.15	11.39	44.29	26.52	29.19	65.24	39.72	56.20		
	2020–2021	11.93	224.18	75.56	75.12	5.87	52.75	23.08	24.16	81.62	21.20	44.86	4.91	3.87
	p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cultivation system × season	ORG × 1999–2000	1.52	230.47	76.52	82.35	7.08	44.08	26.00	29.92	62.50	33.80	61.13	5.29	1.57
	ORG × 2001–2002						43.93	25.16	30.94				3.80	1.24
	ORG × 2007–2008		254.65	79.63	79.34	7.34	49.06	27.59	23.35	68.74	35.13	69.96	5.67	
	ORG × 2008–2009		192.36	70.91	74.60	14.03	46.60	26.77	26.63	55.13	42.15	55.02		
	ORG × 2009–2010		221.64	75.46	80.78	14.89	48.87	24.81	26.32	55.90	39.59	49.24		
	ORG × 2010–2011		203.45	72.73	78.19	10.76	43.71	24.53	31.75	66.13	38.90	57.89		
	ORG × 2020–2021	11.68	234.38	76.22	75.95	5.68	53.25	21.29	25.45	81.95	20.97	45.57	4.73	3.74
	CONV × 1999–2000	1.28	269.71	79.29	84.29	9.30	41.92	27.66	30.41	61.94	35.27	62.21	4.88	1.65
	CONV × 2001–2002						41.17	29.67	28.19				4.76	1.46
	CONV × 2007–2008		271.76	81.78	79.99	7.01	51.12	26.16	22.72	69.12	33.52	69.45	5.44	
	CONV × 2008–2009		175.06	68.50	73.04	13.76	46.71	26.17	27.12	55.81	42.30	55.59		
	CONV × 2009–2010		252.02	77.06	90.00	13.57	50.00	25.59	24.41	55.44	37.71	52.38		
	CONV × 2010–2011		195.45	71.51	76.12	12.03	44.87	28.50	26.62	64.36	40.53	54.51		
	CONV × 2020–2021	12.17	213.99	74.89	74.27	6.06	52.26	24.87	22.87	81.29	21.42	44.15	5.08	4.00
	p-value	0.3378	0.0000	0.0005	0.0514	0.0000	0.0566	0.0000	0.0001	0.3461	0.0000	0.0000	0.0004	0.7610

[1] The *p*-values test the statistical significance of each of the factors. When *p*-values are less than 0.05, these factors have a statistically significant effect for each parameter with a 95% confidence level. [2] Unit fruit weight (W); equatorial fruit diameter (D); fruit height (H); skin color index (skin CI); juice content (J); skin content (S); pulp content (P); brightness (L*); chromaticity to red (a*); chromaticity to yellow (b*); skin thickness (ST); albedo thickness (AT).

Table 3. Chemical quality characteristics of 'Navelina' fruits grown under organic (ORG) and conventional (CONV) conditions in the seven different seasons and probability (*p*-value) for the effects of cultivation method, season, and their interaction.

		Chemical Quality Characteristics [2]								
Factors [1]		**TSS (°Brix)**	**pH**	**TA (%)**	**RI**	**Vit C (mg AA/100 g)**	**EOC (%)**	**Dy (g/mL)**	**Juice CI**	**Seeds (n/Fruit)**
Cultivation system	ORG	11.83	3.64	1.28	11.02	63.70	0.34	1.03	1.50	0.08
	CONV	12.08	3.58	1.36	10.43	57.51	0.28	1.04	1.29	0.00
	p-value	0.104	0.0358	0.1325	0.0713	0.0004	0.0011	0.054	0.733	0.0506
Season	1999–2000	11.42	3.73	0.83	8.94	47.11	0.32	1.05	2.58	0.12
	2001–2002	12.03	3.57	0.77	17.20	50.38	0.43	1.05	2.62	0
	2007–2008	11.66	3.54	1.11	10.72	62.42				
	2008–2009	11.15	3.82	1.60	7.42	59.89	0.35	1.02		
	2009–2010	12.52	3.71	2.98	4.79		0.25	1.01		
	2010–2011	12.30	3.52	1.00	12.41	65.74		1.04		
	2020–2021	12.58	3.37	0.95	13.61	78.10	0.21	1.06	1.02	0
	p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0838
Cultivation system × season	ORG × 1999–2000	11.04	3.66	0.85	8.84	49.46	0.39	1.05	3.44	0.24
	ORG × 2001–2002	12.31	3.51	0.79	16.51	56.85	0.51	1.05	2.31	0
	ORG × 2007–2008	11.45	3.62	0.96	11.94	63.27				
	ORG × 2008–2009	11.24	3.83	1.60	7.52	62.58	0.33	1.03		
	ORG × 2009–2010	11.76	3.85	2.90	5.13		0.25	0.98		
	ORG × 2010–2011	12.92	3.63	0.98	13.21	69.80		1.04		
	ORG × 2020–2021	12.06	3.42	0.89	13.99	80.27	0.21	1.05	1.25	0
	CONV × 1999–2000	11.80	3.80	0.80	9.04	44.77	0.26	1.05	1.73	0
	CONV × 2001–2002	11.74	3.63	0.76	17.88	43.91	0.35	1.05	2.93	0
	CONV × 2007–2008	11.87	3.47	1.25	9.51	61.57				
	CONV × 2008–2009	11.06	3.81	1.59	7.31	57.19	0.37	1.02		
	CONV × 2009–2010	13.28	3.57	3.07	4.46		0.24	1.04		
	CONV × 2010–2011	11.69	3.42	1.02	11.61	61.69		1.05		
	CONV × 2020–2021	13.1	3.33	1.00	13.23	75.94	0.20	1.06	0.78	0
	p-value	0.0000	0.0004	0.1867	0.1006	0.5005	0.0000	0.0001	0.2770	0.0838

[1] The *p*-values test the statistical significance of each of the factors. When *p*-values are less than 0.05, these factors have a statistically significant effect for each parameter with a 95% confidence level. [2] Total soluble solids content (TSS); total acidity (TA); ripeness index (RI); vitamin C concentration (Vit C); essential oils concentration (EOC); juice density (Dy); juice color index (juice CI); number of seeds (seeds).

Table 4. Physical quality characteristics of 'Clemenules' fruits grown under organic (ORG) and conventional (CONV) conditions in the seven different seasons and probability (*p*-value) for the effects of cultivation method, season, and their interaction.

		Physical Quality Characteristics [2]												
Factors [1]		**Shape**	**W (g/fruit)**	**D (mm)**	**H (mm)**	**Skin CI**	**J (%)**	**S (%)**	**P (%)**	**L***	**a***	**b***	**ST (mm)**	**AT (mm)**
Cultivation system	ORG	6.88	90.56	58.89	49.93	11.33	43.03	23.11	33.86	64.15	36.35	50.11	2.75	1.45
	CONV	6.80	81.87	56.13	47.30	10.13	40.55	26.81	32.65	65.50	34.18	52.04	2.28	1.30
	p-value	0.721	0.0001	0.0000	0.0000	0.0000	0.0041	0.0000	0.1502	0.0000	0.0000	0.0000	0.0136	0.2922
Season	1999–2000	2.76	70.82	55.06	45.41	10.01	38.62	26.84	34.53	60.66	35.56	58.98	2.59	1.48
	2001–2002	8.16	106.17	62.05	50.60	8.77	46.05	22.69	31.26				2.37	0.92
	2007–2008						41.32	28.78	29.91					
	2008–2009		74.46	53.79	47.23	15.04	37.74	23.19	39.07	53.90	41.87	52.38		
	2009–2010		77.88	55.01	48.65	12.83	38.84	27.21	33.95	66.73	39.49	46.89		
	2010–2011		81.16	56.57	50.05	12.23	39.41	23.86	36.74	62.80	40.85	54.69		
	2020–2021	9.59	106.80	62.59	49.75	5.50	50.54	22.12	27.34	80.04	18.57	42.45	2.59	1.73
	p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0656	0.0000
Cultivation system × season	ORG × 1999–2000	2.52	82.92	59.23	50.02	10.94	41.63	26.03	32.33	59.59	37.30	57.41	3.17	1.68
	ORG × 2001–2002	8.46	119.36	64.83	50.60	9.23	43.87	20.57	35.56				2.53	0.94
	ORG × 2007–2008						45.80	26.11	28.09					
	ORG × 2008–2009		77.67	55.23	49.29	15.94	32.99	20.46	46.56	52.99	43.55	51.63		
	ORG × 2009–2010		77.67	55.17	49.07	12.71	40.27	27.39	32.34	67.22	39.77	47.42		
	ORG × 2010–2011		81.95	57.04	51.30	13.51	44.40	20.16	35.48	60.94	42.12	52.07		
	ORG × 2020–2021	9.64	103.81	61.82	49.28	5.68	52.29	21.04	26.68	80.00	19.01	42.02	2.54	1.74
	CONV × 1999–2000	3.0	58.72	50.89	40.81	9.06	35.62	27.65	36.73	61.73	33.81	60.54	2.0	1.27
	CONV × 2001–2002	7.85	92.98	59.27	50.59	8.31	48.23	24.81	26.95				2.21	0.90
	CONV × 2007–2008						36.83	31.44	31.72					
	CONV × 2008–2009		71.25	52.35	45.16	14.15	42.50	25.92	31.58	54.80	40.19	53.13		
	CONV × 2009–2010		78.09	54.84	48.22	12.97	37.41	27.04	35.55	66.24	39.21	46.37		
	CONV × 2010–2011		80.36	56.10	48.80	10.96	34.43	27.57	38.00	64.65	39.58	57.31		
	CONV × 2020–2021	9.54	109.79	63.35	50.21	5.32	48.80	23.20	27.99	80.09	18.13	42.88	2.63	1.71
	p-value	0.2002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0380	0.0000	0.0061	0.6561

[1] The *p*-values test the statistical significance of each of the factors. When *p*-values are less than 0.05, these factors have a statistically significant effect for each parameter with a 95% confidence level. [2] Unit fruit weight (W); equatorial fruit diameter (D); fruit height (H); skin color index (skin CI); juice content (J); skin content (S); pulp content (P); brightness (L*); chromaticity to red (a*); chromaticity to yellow (b*); skin thickness (ST); albedo thickness (AT).

Table 5. Chemical quality characteristics of 'Clemenules' fruits grown under organic (ORG) and conventional (CONV) conditions in the seven different seasons and probability (*p*-value) for the effects of cultivation method, season, and their interaction.

		Chemical Quality Characteristics [2]								
Factors [1]		**TSS (°Brix)**	**pH**	**TA (%)**	**RI**	**Vit C (mg AA/100 g)**	**EOC (%)**	**Dy (g/mL)**	**Juice CI**	**Seeds (n/Fruit)**
Cultivation system	ORG	12.00	3.82	1.05	13.91	55.58	0.36	1.05	3.33	12.34
	CONV	12.00	3.80	1.15	13.52	53.30	0.29	1.03	3.55	2.62
	p-value	0.9841	0.5200	0.0983	0.5033	0.3841	0.0002	0.1504	0.5795	0.0002
Season	1999–2000	11.32	4.22	0.48	16.36	46.08	0.40	1.06	5.88	12.66
	2001–2002	12.58	3.63	0.83	15.26	43.80	0.53	1.05	2.93	2.54
	2007–2008	10.77	3.78	0.76	14.25	55.47				
	2008–2009	12.77	4.01	1.29	10.28	58.96	0.29	1.03		
	2009–2010	12.31	3.71	2.84	5.17		0.23	1.01		
	2010–2011	12.58	3.72	0.73	17.90	60.28		1.04		
	2020–2021	11.68	3.61	0.76	16.79	62.06	0.18	1.06	1.52	7.32
	p-value	0.0019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cultivation system × season	ORG × 1999–2000	10.16	4.20	0.43	14.30	47.13	0.24	1.04	6.03	24.33
	ORG × 2001–2002	13.0	3.69	0.79	16.53	51.31	0.80	1.06	2.74	3.89
	ORG × 2007–2008	10.9	3.79	0.79	13.81	55.46				
	ORG × 2008–2009	12.81	4.03	1.24	10.77	54.61	0.28	1.04		
	ORG × 2009–2010	12.52	3.73	2.71	6.17		0.28	1.06		
	ORG × 2010–2011	12.27	3.72	0.72	17.51	59.65		1.03		
	ORG × 2020–2021	12.31	3.61	0.69	18.28	65.33	0.18	1.05	1.23	8.79
	CONV × 1999–2000	12.47	4.24	0.54	18.43	45.03	0.56	1.07	5.74	1.0
	CONV × 2001–2002	12.17	3.56	0.87	13.98	36.29	0.26	1.05	3.11	1.18
	CONV × 2007–2008	10.65	3.78	0.73	14.70	55.49				
	CONV × 2008–2009	12.73	3.99	1.34	9.79	63.30	0.29	1.02		
	CONV × 2009–2010	12.1	3.69	2.98	4.17		0.18	0.96		
	CONV × 2010–2011	12.89	3.73	0.74	18.28	60.92		1.04		
	CONV × 2020–2021	11.04	3.61	0.83	15.30	58.79	0.18	1.06	1.82	5.66
	p-value	0.0688	0.9113	0.4327	0.0000	0.0000	0.0000	0.0000	0.5675	0.0308

[1] The *p*-values test the statistical significance of each of the factors. When *p*-values are less than 0.05, these factors have a statistically significant effect for each parameter with a 95% confidence level. [2] Total soluble solids content (TSS); total acidity (TA); ripeness index (RI); vitamin C concentration (Vit C); essential oils concentration (EOC); juice density (Dy); juice color index (juice CI); number of seeds (seeds).

Significant differences are observed in several physical quality parameters of 'Clemenules' fruits (Table 4). Particularly, when the effect of the cultivation method is considered, 'Clemenules' fruits grown in the organic cultivation method had significantly higher mean values of fresh weight (90.56 g) than those grown under the conventional system (81.87 g). The mean values of diameter and height were also significantly higher in the organic 'Clemenules' fruits (58.89 mm and 49.93 mm, respectively) compared to the mean values found in fruits grown under conventional practice (56.13 mm and 47.30 mm, respectively). The same trend is detected for the color index of the peel. This parameter was significantly higher in organically grown 'Clemenules' fruits (11.33) than conventionally grown 'Clemenules' samples (10.13), possibly due to the higher value of parameter a*. The percentage of juice was significantly higher in the organic fruits (43.03%) than in the conventional ones (40.55%). The cultivation method also affects the skin thickness, which was significantly higher in organic 'Clemenules' (2.75 mm) than in conventional ones (2.28 mm). However, the total skin content was higher in conventionally produced fruits. The cropping system × season interaction affects all physical parameters except shape and albedo thickness (Table 4).

The significant difference found in 'Clemenules' fruit, due to the growing system effect, for chemical and nutritional parameters, was in the concentration of essential oils in the skin and the number of seeds per fruit (Table 5). Organic 'Clemenules' fruit samples had a significantly higher content of essential oils, 0.36 g per 100 g of peel, compared to 0.29 g per 100 g in conventional peel fruits. The number of seeds per fruit was statistically higher in organic 'Clemenules' than in conventional ones (12 and 3 seeds, respectively). The vitamin C concentration was also higher in the organic fruits, although without statistical differences, with mean values of 55.58 mg per 100 g of juice compared to 53.30 mg per 100 g of juice for the conventional ones. Finally, significant differences for the cultivation system × season interaction found in 'Clemenules' samples were in the ripeness index, the vitamin C concentration, and the percentage of essential oils (Table 5). In the parameters where no statistically significant interaction effects are observed, the farming system shows the same trend in all seasons.

3.2. Frequency Mosaic Graph: Fruit Shape Typing

The mosaic graphs show the results of the contingency table (cross-frequency table), using rectangles whose area is proportional to the frequency of each of the class crossings. The height of the rectangles (ordinate axis) is proportional to the percentage distribution of the corresponding variable and the base of the rectangle (abscissa axis) is proportional to the percentage distribution of the other variables. Figure 2 shows the mosaic graph of the shape frequencies of 'Navelina' and 'Clemenules' citrus fruit grown under organic conditions, and Figure 3 represents the same graphical parameter for conventional oranges and mandarins.

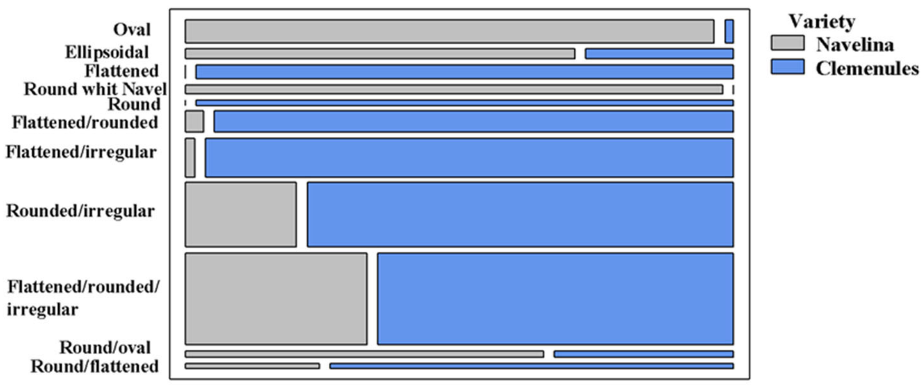

Figure 2. Mosaic graphic of frequencies of the shape of organic citrus 'Navelina' and 'Clemenules' varieties.

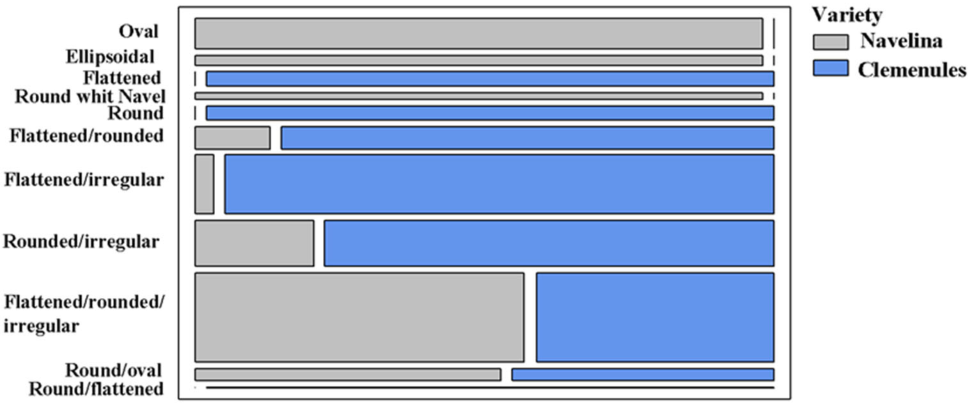

Figure 3. Mosaic graphic of frequencies of the shape of conventional citrus 'Navelina' and 'Clemenules' varieties.

A higher incidence of oval shape is observed for the citrus variety 'Navelina' compared to 'Clemenules', with a higher frequency of oval shape for conventional 'Navelina' fruits. The flattened shape is more prevalent for the 'Clemenules' variety, regardless of the cropping system. The mosaic graphs show that the irregularly rounded shape has a higher incidence in the fruits for the 'Clemenules' variety than in those of the 'Navelina' oranges, and in both, higher percentages are observed for the organic fruits. Conventional 'Clemenules' fruits showed a higher incidence of flattened/irregular shapes compared to 'Navelina' oranges. Figure 2 shows a higher frequency of flattened/rounded/irregular shapes for organic mandarins, while in Figure 3, the frequency is higher for conventional oranges.

3.3. Typification of the Fruits According to the Production System

Discriminant analysis is applied for explanatory and predictive purposes. With the explanatory use, the aim is to determine the contribution of each classifier variable in the correct classification of each individual (citrus) in the production system (organic and conventional). With the predictive application, it will be possible to determine in the future the group to which an individual belongs, for which the values taken by the classifying variables are known.

Two statistically significant (95% confidence level) and discriminant models have been obtained, which can help predict the production system to which the citrus fruits belong (Table 6). These models can be used to typify and predict the production system of the observations.

Table 6. Eigenvalues of the discriminant models in the classification of citrus fruits.

	Statistical Values					
Standardized Classifier Function	Eigenvalue	Canonical Correlation	Lambda of Wilks	Chi-Square	Freedom Degrees	p-Value
[1] Model 1 = −84.353 + 2.91167 × D − 0.498518 × W + 0.799272×H	0.00407229	0.06368	0.99594	10.4181	3	0.0153
[2] Model 2 = −0.773399×ST + 0.741901 × AT + 1.17359 × S	0.271197	0.46189	0.78666	186.088	3	0.0000

[1] Equatorial fruit diameter (D), unit fruit weight (W), fruit height (H). [2] Skin thickness (ST), albedo thickness, skin content (S).

To realize the two models, different analyses were carried out to arrive at an adequate classificatory function, with the main objective being that a reduced and simple number of parameters can be used for the successful classification of citrus fruits. A significant model (95% confidence level) was obtained using only physical parameters (unit weight, diameter, height, and the color parameters L*, a*, b*, CI). With the results of this preliminary study, the three parameters with the greatest weight in the classification function were selected and the analysis was performed again, where 2567 cases were used to develop model 1, which discriminates between organic and conventional systems, using three predictor variables. Model 1 allows 53.72% of the fruits to be classified correctly, using only the parameters of diameter, height, and unit weight of the citrus fruits. When the other parameters (physical, chemical, and nutritional) are used, a significant function is obtained that allows 79.47% of the cases to be classified correctly. Although the classification level is high, the resulting classification function is not valid because it requires a large number of parameters. The last analysis carried out includes only the parameters related to the skin measurement (skin thickness, albedo thickness, and skin content). Model 2 allows us to correctly classify fruits in 71.89% of the cases. A total of 779 cases were used to develop model 2, which discriminates between organic and conventional systems, using the three predictor variables, easily measurable from the skin of the fruits.

Table 7 shows that the classification of the observations (citrus fruits) based on Model 1 allows us to correctly classify, on average, 53.72% of the cases. Of the 1482 observations of organic fruits, 880 (59.38%) are correctly classified. Of the 1085 observations of conventional citrus fruits, 499 (45.99%) are correctly classified. Model 2, on average, allows 71.89% of the observations to be correctly classified.

Table 7. Classification of fruits by production system using the two models.

		Production System	**Predicted Membership Group**	
			Organic	**Conventional**
Model 1	Numerical count	Organic	880	602
		Conventional	586	499
	Percentage count	Organic	59.38%	40.62%
		Conventional	54.01%	45.99%
Model 2	Numerical count	Organic	323	103
		Conventional	116	237
	Percentage count	Organic	75.82%	24.18%
		Conventional	32.86%	67.14%

Figure 4 shows the scatter diagram of model 1 (left) and model 2 (right), according to the independent variables selected in each case. The highest level of separation between organic and conventional citrus fruits is observed with model 2.

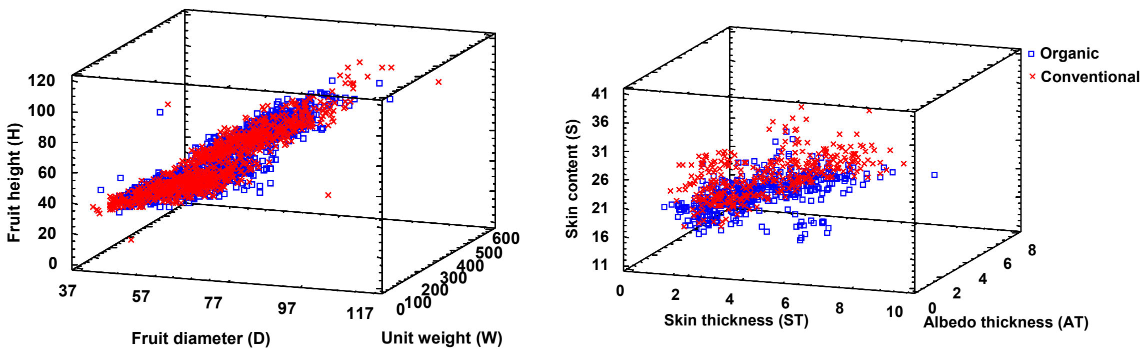

Figure 4. Scatterplot of model 1 (**left**) and model 2 (**right**) of the selected independent variables.

4. Discussion

Fruit quality is the result of complex interactions of genetic factors (plant crop and cultivar), environmental conditions, cultivation practices, harvesting time, and postharvest handling [10,43,44]. Our results suggest that there are considerable differences in various physical, chemical, and nutritional quality parameters in the citrus samples analyzed due to the different production systems. Citrus shape is strongly correlated to variety [45]. The results of this study show that 'Navelina' fruits are mainly oval in shape, regardless of farming system. For fruits of the 'Clemenules' variety, although they are oval and round in shape, in all cases, the main characteristic was the flattened shape. The higher percentage of irregular shapes in organic citrus fruits was expected to be an important index of biodiversity that characterizes organic vegetables and fruits. This can be a drawback for the marketing of fruits, but responsible organic consumers are aware of this variability in the fresh product [46,47].

The characteristic color of citrus fruits is mainly due to the presence of carotenoids, and their composition is influenced by several factors, including geographical origin, fruit ripeness, and, particularly, variety [48]. Color is one of the most remarkable features of the different citrus species and cultivars and a key factor of external and internal quality and consumer acceptance [11]. In fact, it is of great importance in evaluating commercial quality, and there have been attempts to quantify the sensation of color perceived by the brain through the human eye, although some fruit degreening in conventional practices by exogenous exposure to the ripening hormone ethylene could confuse the will of the consumer [49]. The skin color index shows significant differences in the case of both citrus varieties studied: in 'Clemenules' fruit, color values observed in organically produced fruit were higher, while in 'Navelina' oranges, the opposite was found, with higher values for conventional fruits, finding similarity with the results of other studies [50].

The varietal difference is observed in the size, being the fruits of 'Navelina' heavier than those of 'Clemenules'. The height of the fruits is significantly higher in citrus fruits of the 'Navelina' variety when the production system is organic. Fruit diameter is not significant, regardless of the variety. The cultivation system is not significant for the unit weight of the 'Navelina' fruits, with the weight ranging between 222.82 and 229.66 g/fruit. These grammages are within the caliber values for this variety [51]. Organically produced 'Clemenules' fruits are on average 9.6% heavier than conventional ones. This means that under organic production conditions, weights similar to or greater than those obtained with conventional methods can be obtained. Consequently, organic fruits reach the standards of commercial quality, related to the caliber.

We found significant differences in skin percentage in 'Navelina' and 'Clemenules' fruits, which are higher for conventional fruits. Similar results are reported [50] in the same varieties, but only in one growing season, where a lower skin percentage was found in citrus fruits produced on organic farms. In 'Navelina' oranges, the skin content of conventionally produced fruits is 26.95% compared to a value of 25.17% for organically produced fruits, which means that the amount of juice and pulp in conventionally produced 'Navelina' oranges is 73.05%, while in the case of organically produced 'Navelina' oranges, the pulp and juice content is 74.83%. In 'Clemenules' mandarins, the amount of juice and pulp from conventional production is 73.19%, while for organically produced mandarins, the pulp and juice content is 76.89%, which means that organic fruits are juicier than conventional ones. The skin levels of organic fruits are low, which means that organic fertilization invests more energy in the synthesis of juice and pulp, while chemical fertilization and, above all, excess nitrogen fertilization, concentrate on skin production. Some authors confirm that organic fertilizer treatments tend to decrease skin content and increase juice content in several citrus cultivars compared to conventional fertilizers [10,52–55], but variable seasonal conditions and variety may reverse the results [56]. When higher juice content occurs in conventional oranges, this effect could be attributed to the higher water concentration present in conventional fruits due to excess nitrogen fertilization, as reported by Neuhoff et al. [57].

The peel color, fruit size, and fruit shape contribute to the external appearance and influence consumers' attention and appreciation. Satsumas and Clementines are considered medium–small to medium-sized; common and Mediterranean mandarins are medium-sized. On the other hand, experience and market demands in the distribution of organic food mean that the fruits that reach the market are very homogeneous. Differences due to external attributes are only observed in markets with a higher degree of complicity with producers, and in this case, it is no longer a commercial problem. In addition, the consumption of irregular foods contributes to reducing food waste.

The higher number of seeds found in our work for the organic citrus fruits 'Navelina' and 'Clemenules' is consistent with what is reported in the literature [50]. The presence or absence of seeds in fruit is a determining factor of its commercial value. Citrus fruits which have a high number of seeds per fruit are generally not preferred for fresh consumption and are not suitable for the processing industry for juice extraction [44]. However, the presence of seeds in fruit is due to cross-pollination, favored mainly by bees. Their presence is an index of the increased biodiversity in organic fields, as the pesticide-free ecosystem favors the presence of pollinating fauna [58]. The importance of bee pollination for food crops has been widely recognized. In addition to improving the yield of some crops, bee pollination contributes to increasing the nutritional value, improving the quality, and prolonging the shelf life of many fruits and vegetables [59]. Regardless, the fruits of the present study can be classified as 'low-seeded' since according to commercial criteria, a 'low-seeded' variety should have no more than two seeds per fruit in a random sample of twenty-five fruits, with no fruit containing more than four seeds [60].

We found a significantly higher level of vitamin C in organic 'Navelina' oranges than in oranges grown under conventional practices. Likewise, in the case of 'Clemenules' fruits, although the result is not statistically significant, we found a higher vitamin C concentration in organic mandarins. These results are in agreement with those reported by other authors who observed a higher concentration of vitamin C in fruit yielded with an organic cultivation method compared to conventional cultivation systems, in citrus cultivars and varieties [10,11,29,55]. This vitamin is one of the most important antioxidant compounds in plant cells and one of the main contributors to the health benefits attributed to consumption. Recently, its importance in the Coronavirus disease 2019 (COVID-19) has also been highlighted due to its role in modulating the immune system and cellular defense against oxidative stress associated with infection [61]. In many crops, increased vitamin C concentration also prolongs the food's shelf-life [11]. In the case of oranges, studies have shown that the shelf life of organically grown oranges increases by five weeks compared to conventional oranges [62]. Vitamin C concentration, in different citrus species, is inversely correlated with the nitrogen supply [63]. Therefore, the lower vitamin C concentration in conventional fruits could be due to the nitrogen application from synthetic fertilizers immediately available in these crops, as the abuse of nitrogen fertilizers leads to an increase in the relative water content of the plant tissue, then a dilution effect, and induces an increase in the concentration of nitrate ions in plants, then simultaneously the decrease in ascorbic acid, which is an inhibitor in the formation of carcinogenic nitrous compounds [14,64].

The mean values of vitamin C concentration found in this work for 'Navelina' and 'Clemenules' fruits are included in the literature range, where the vitamin C content in commercial orange juices is between 35 and 74 mg per 100 mL of juice [60]. Furthermore, in our experiment, the vitamin C concentration was significantly higher in 'Navelina' fruit than in 'Clemenules' citrus, regardless of the production system. This is in agreement with other authors [14,50], who reported that the vitamin C concentration in oranges is generally higher than in mandarins. This confirms the influence of genetic factors on fruit quality [43,62]. Our long-term study concludes that, on average, 100 mL of organic 'Clemenules' juice provides 4.1% more vitamin C than its conventional counterpart. In the case of 'Navelina', organic production can increase the vitamin C content in citrus juice by almost 10%.

Another significant difference related to the cultivation method is highlighted for the pH parameter in citrus juice, which was higher in organic 'Navelina' fruits than in conventional ones (Table 2). The result of pH in juice from organic 'Navelina' fruits is inconsistent with that of Duarte et al. [10], who reported a higher mean pH value in organic fruits than those found in fruits grown with conventional practices, possibly due to the presence of other acids present in conventional fruits that influence the decrease in the pH value. There is a logical trend between the pH value and the total acidity of the juice, since juices with a higher pH value have lower total acidity content. There is also a slight relationship between acidity parameters and TSS, so that when juices are more acidic, TSS increases, decreasing the value of the ripeness index. Some authors have found no differences in the acidity levels and soluble solids content of the fruit when contrasting the effect of chemical and organic fertilizers [65]. Total soluble solids content and total acidity determine the organoleptic properties of fruits and the balance ratio.

Total juice acidity had the same trend in the two citrus varieties and in all seasons, with the highest acidity in fruits from organic systems. Fruit height, juice percentage, brightness, flesh thickness, ripeness index, vitamin C content, juice color index, and number of seeds of 'Navelina' fruits are parameters for which the cultivation system shows the same tendency in all seasons. In the case of 'Clemenules' fruits, the color parameter a*, thickness of the fruit flesh, soluble solids content, pH, and juice color index are parameters for which the cultivation system also shows the same trend in all seasons studied.

The exposure of plants to aggressive and stressful situations, such as pathogen attack, leads to a considerable increase in secondary metabolites as a defense mechanism in the absence of synthetic fertilizers and pesticides commonly used in the conventional growing system. Then, the absence of chemical resources that characterizes organic practices is related to a higher concentration of essential oils in organic fresh vegetables and fruits than in conventionally grown ones [47,66]. In addition to sugars and acids, volatile flavorings can also influence flavor perception. Our results about the concentration of essential oils in organic and conventional 'Navelina' and 'Clemenules' fruits are in line with previous statements and in agreement with other authors who indicate that citrus peels are an important source of essential oils [9]. These volatile compounds not only enhance the organoleptic profile of citrus fruit, due to their pleasant smell, but also possess excellent properties, such as antimicrobial, anti-inflammatory, antitumor, antioxidant, and neuroprotective activities. In fact, these characteristics have long been widely used in foods, cosmetics, and pharmaceuticals [7]. Our long-term study concluded that, on average, 100 g of peel from organic 'Navelina' fruits provide 17.65% more essential oils than their conventional counterparts. In the case of 'Clemenules' fruits, organic production can increase the essential oil content by almost 19.50%.

The discriminant function has been used to successfully verify the identity of organic foods [67]. It has been employed in the classification and differentiation of seven orange varieties using several chemometric techniques [68]. It has even been successfully used in the classification of organic and conventional citrus by detecting markers linked to nitrogen metabolism [55]. In both cases, the parameters chosen for citrus classification require complex analyses and/or have been performed with a small number of samples. Cuevas et al. [69] provided a methodology based on profiling stable isotope polyphenols, among other quality parameters, to classify citrus fruits using data fusion techniques. In this case, the number of organic fruits analyzed was 126 and the number of conventional fruits was 132. The present work amplifies the scientific gap in the classification of organic citrus fruits based on quality parameters obtained from seven study campaigns, and the result is two classification equations, both obtained with simple analytical parameters.

Consumers and farmers need tools that can ensure trust and prevent organic food fraud. For Danezis et al. [70], verifying the authenticity of organically produced products is also of interest to the scientific community and regulators. The models obtained in this work will successfully predict the production system and generate more confidence among consumers.

5. Conclusions

The long-term results of this work allow us to provide verified information on the global quality of organic 'Navelina' orange and 'Clemenules' mandarin fruits. Organic systems produce citrus fruits that meet market criteria standards in terms of color and size, providing a visual quality accepted by consumers. In line with the growing demand for environmentally friendly organic food products that guarantee a lower impact, the daily consumption of organic citrus fruits is recommended to improve human health due to the antioxidant properties of vitamin C present in concentrations 4.1% higher in 'Clemenules' organic and 10% higher in 'Navelina' organic fruits. In addition to the higher vitamin value, organic citrus fruits contain higher concentrations of essential oils that generate a more aromatic sensation, conveying the characteristic and authentic aroma of citrus fruits. The high number of results obtained in the study period has allowed us to obtain two discriminating equations that use easy-to-measure parameters to successfully classify organic citrus fruits. The classification and prediction models obtained can be used by both national organizations/fruit processors and international control authorities, and constitute useful tools to help predict the purity/authenticity of organic citrus fruits. The results obtained reinforce the idea of the high quality of organic food and are strongly supported by the long-term study.

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