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COMPARISON OF QUALITY BETWEEN ORGANIC AND CONVENTIONAL STRAWBERRIES FROM MULTIPLE FARMS[1]

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ABSTRACT-Strawberries are appreciated worldwide. However, a large quantity of agrochemicals is used in their production because of their highly susceptibility to pests and diseases. Many studies have compared the quality of fruits grown on organic production system and conventional system, but results are often contradictory. The aim of this study was to compare the strawberries fruits quality (*Fragaria ananassa* Duch) grown under organic and conventional production systems. Seven pairs of farms were selected, and fruits were collected at different times and production locations. Experimental design was completely randomized, with a 2 x 5 factorial scheme (two production system types x five storage periods) with four replicates of ten strawberries. Strawberries produced under organic production system exhibited higher soluble solids contents and firmer pulp than those produced under conventional system. Weight loss, titratable acidity and ascorbic acid concentrations were not influenced by farming systems. Conventional system resulted in fruits with lower rot index, while strawberries produced under organic production system exhibited higher soluble solids contents and firmer pulp. Thus, in this study it was observed that each production system was responsible for benefit different attributes in strawberries.
Index terms: *Fragaria* spp., storage, physical and chemical parameters.

COMPARAÇÃO DA QUALIDADE DE MORANGOS ORGÂNICOS E CONVENCIONAIS DE VÁRIAS PROPRIEDADES

RESUMO- Morangos são apreciados em todo o mundo. No entanto, uma grande quantidade de produtos agroquímicos é utilizada na sua produção por serem muito susceptíveis a pragas e doenças. Muitos estudos têm comparado à qualidade de frutos provenientes do sistema orgânico e do sistema convencional, mas os resultados são contraditórios. O objetivo deste estudo foi comparar a qualidade de morangos (*Fragaria ananassa* Duch) cultivados sob métodos de cultivo orgânico e convencional. Sete pares de fazendas foram selecionados, e frutos foram coletados em diferentes momentos e locais de produção. O delineamento experimental foi inteiramente casualizado, com esquema fatorial 2 x 5 (dois tipos de cultivo x cinco períodos de armazenamento), com quatro repetições. Morangos produzidos no sistema de cultivo orgânico apresentaram maiores teores de sólidos solúveis e polpa mais firme que os produzidos no sistema convencional. A perda de massa fresca, acidez titulável e os teores de ácido ascórbico não foram influenciados pelos sistemas de cultivo. O sistema convencional resultou em frutos com menores índices de podridão, enquanto que morangos provenientes do sistema de cultivo convencional exibiram frutos com conteúdo maior de sólidos solúveis e polpa firme. Desta forma, neste trabalho foi observado que cada sistema de cultivo foi responsável em beneficiar diferentes atributos de qualidade em morangos.
Termos para indexação: *Fragaria* spp., armazenamento, parâmetros físicos e químicos.

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INTRODUCTION

Strawberries are one of the most commonly consumed fruits worldwide, mostly due to their appearance, flavor and nutritional characteristics. However, their production show many difficulties associated with their high susceptibility to pests and diseases. Like other countries, strawberry production in Brazil uses agrochemicals intensively, receiving up to 45 sprayings during one production cycle (DAROLT, 2003).

According to the Program of Food Pesticide Residue Analysis (Brazil - PARA), of the National Health Surveillance Agency, 63.4% of strawberry samples analyzed in 2010 were classified as unsatisfactory due to an unacceptable employment of unregistered agrochemicals for this crop or use of agrochemical above of the maximum levels allowed by Brazilian legislation (ANVISA, 2016).

Due to an intensive use of pesticides in conventional productions system, organic cultivation system has been gaining prominence, supplying fruits without chemical residues. In addition, organic strawberries may be distinguished from those produced conventionally in terms of quality, although results found in literature still remain contradictory (OLIVEIRA et al., 2013; ÁVILA et al., 2012; CRECENTE-CAMPO et al., 2012; CAMARGO et al., 2011; CAYELA et al., 1997).

Studies comparing conventional and organic production methods and fruits quality are often difficult to perform, involving a large number of factors, leading with non-conclusive results (VALLVERDÚ-QUERALT; LAMUELA-RAVENTÓS, 2015). Crop management (mineral nutrition, soil management, sprayings, irrigation, etc.), environmental factor (temperature, humidity and soil texture) (AKHTOU; RECAMALES, 2014) and farm history and technology used by producers are some of a large extrinsic factors influencing fruits quality depending on production system.

Despite the difficulty of obtaining conclusive results in studies associating production systems, most research compares only single properties (Organic *vs.* Conventional). The aim of this study was compare strawberries quality of seven commercial farm pairs, having one organic system farm and conventional systems farm composing each pair, previously selected in one of the most important producing regions of Brazil.

MATERIALS AND METHODS

Initially, it was identified organic and conventional strawberry farms in São Paulo and Minas Gerais States, Brazil. These farms were grouped into seven pairs. Each pair had a very similar farm conditions in terms of strawberry cultivar, origin of seedlings, age of plants, irrigation system and technology level. Farms within each pair were spatially close enough to ensure similar conditions of soil and microclimate, being located in a maximum of 15 km away.

'Oso Grande' strawberry was grown in six farms pairs. Each two pairs were grown in one of following cities of São Paulo State: Atibaia (23º 07' 38" S, 46º 34' 27" W), Jarinú (23º 06' 03" S, 46º 43' 40" W) and Monte Alegre do Sul (22º 40' 55" S, 46º 40' 51" W). 'Albion' strawberry was grown at Senador Amaral city (22º 35' 13" S, 46º 10' 37" W) in Minas Gerais State.

Harvests of each pair were performed in the same morning, between 8 and 10 a.m., from July 2012 to January 2013. Fruits harvest were done when maturation stage corresponded to ¾ of red color peel. Then, strawberries were placed in polyethylene terephthalate clamshells (capacity 300 g). Packages containing strawberries were placed in cardboard boxes, each one containing four packages, and stored temporarily in expanded polystyrene boxes containing ice cubes to keep temperature at 17 and 19 ºC. Fruits were taken to Postharvest Laboratory of Horticultural Products of "Luiz de Queiroz" Agriculture College, University of São Paulo (Brazil), located approximately 130 km from producing region of the state of São Paulo and 240 km from Senador Amaral (MG).

Strawberries were stored in cold rooms at 15±1 ºC and 90 ± 5% of relative humidity, simulating Brazilian market conditions. Quality evaluations were performed on the harvest day and every two days until the end of storage period, which varied between 4 and 8 days. Experiments were performed using a completely randomized experimental design, with a 2 x 5 factorial scheme (two production systems x five storage times) and four replicates of ten strawberries each.

Strawberries color was measured with a Minolta colorimeter (CR-300) using lightness (L*), which represents black to white variation and a* coordinate, which represents green (-a) to red (+a) variation. Data were recorded using D65 illuminant and a 2° standard observer as a reference system. Measurements were done in two opposite sides of four replications of ten fruits at equatorial fruit section. Firmness was also measured in two opposite sides of ten strawberries of each replicate, using a digital penetrometer (53200 Sammar Tr – Turoni, Forli, Italy) with a 6-mm diameter probe. Results were expressed in Newton (N). Soluble solid content was measured using a digital refractometer (Palette 101, Atago) and values were expressed in ºBrix. Titratable acidity and ascorbic acid contents were measured by titration and results expressed in percentage of citric acid and mg 100 g^{-1} pulp, respectively (AOAC, 2005). Weight loss was obtained by weighting ten strawberries individually before and after storage. Data were expressed in percentage of initial mass. Anthocyanin content was performed by spectrophotometry and results were expressed in mg $100g^{-1}$ of fruit pulp (pelargonidin-3-glucoside).

Rot index was determined visually, based on rot incidence and severity. Strawberries presenting rot symptoms up to approximately 10% of their surface were considered "fruits with slight rot"; fruits with more than 11% of impaired surface were considered "rotting fruits". The results were expressed in percentage.

Statistical analyses were performed using SAS (*Statistical Analysis System*) software. The Box-Cox best power procedure was used to identify the best data transformation. The homogeneity of variance was tested, and when necessary, data were transformed or tested using non-parametric methods. Data were analyzed by ANOVA and means compared using a Tukey's test at significance level 0.05.

RESULTS AND DISCUSSION

Storage Period

It was observed decrease in lightness (L*) for strawberries along postharvest storage for both production systems (Fig 1A). Strawberries of conventional farming showed a great reduction of lightness values after 2nd day, but not significant or perceptible by naked eye. This result agrees with Ávila et al. (2012) study, where authors also reported no effect of production systems in 'Camarosa' and 'Camino Real' lightness (L*). Comparing the seven pairs it was not possible to point a production system that promote better lightness (Tab 1). It was found three pairs with no differences, other three pairs where lightness was higher for fruits from organic system and one pair where fruits from conventional system were lightener (Tab 1).

There were significant differences between strawberry production systems during storage related to green/red color (a* coordinate). However, it was not possible observe any tendency related to system production, once pair I had higher values for fruits from conventional production and pairs III, V, VI and VII higher values of a* for fruits from organic production. Likewise, pairs II and IV did not showed significant differences in this work (Tab 1).

Firmness for conventional strawberries decreased through storage period, while organic ones showed a slight initial increase followed by a decrease. However, both organic and conventional strawberries reached similar firmness at the end of storage period (Fig 1C).

There were no significant differences between production systems for weight loss, which is consistent with Lima et al. (2012) and Lima (2015) in strawberries cultivated similarly. Weight loss reduction in strawberries reached 7% on the 8th day. According to García et al. (1998), strawberries lose commercial value when weight loss is greater than 6%, indicating that, the analyzed fruits had showed marketing conditions along 6 days.

Soluble solid contents did not change during storage and it was higher in organic system fruits for pairs I, II, III, IV, and V (Fig 1D), which was similar to those results described by Cayuela et al. (1997) in 'Chandler' strawberry. According to Seufert et al. (2012), this behavior can be explained by soil fertilization in organic system, carried out by methods and tools that promote slow nutrients release to plant, unlike conventional system. Although it was observed this trend for soluble solids content, it was not possible directly associate these higher values with organic system, once two pairs showed similarity between systems.

Titratable acidity does not seem to be related to cultivation system, since three pairs of organic cultivations exhibited higher average, while the other four highest values were evaluated in organic farming. This result is opposite trend to before reported by Camargo et al. (2011) and Lima et al. (2012) in 'Oso Grande' strawberries.

It was observed an increase in ascorbic acid content during storage period (Fig 1E) for strawberries from both production systems. Maximum values found were 92.6 mg 100 g^{-1} (organic) and 68.9 mg 100 g^{-1} (conventional) at the end of storage. Cayuela et al. (1997) also reported similar results. Comparable results were verified for anthocyanin content, with no difference between production systems. For anthocyanins, maximum value observed was 27 mg 100 g^{-1}. Cantillano et al.

(2012) observed a higher content of anthocyanins in 'Camarosa' and 'Camino Real' strawberries produced by conventional system, while Camargo et al. (2011) described opposite performance for 'Oso Grande' strawberries.

Regardless the type of production system, there was an increase in rot index during postharvest storage (Fig 1F). Indexes registered on 8th day were 89.1% for organic strawberries and 54.1% for those conventional. Ávila et al. (2012) did not find differences in this parameter in organic or conventional 'Camino Real' and 'Camarosa' strawberries stored for 8 days at 1 °C. Lima et al. (2012) reported similar results in fruits of the same species stored under environmental condition.

Cultivation System

Organic strawberries exhibited higher lightness (L*), green/red modification (a*) values, firmness and soluble solids contents than conventional strawberries (Table 1).

Lightness value varied between field pairs (Table 1). Organic production system left strawberries less dark than conventional system for three, of six farm pairs, coming from São Paulo State. The remaining other three pairs kept similar lightness. Overall, considering all seven field pairs, organic strawberries revealed tendency to lighter external color than those cultivated in conventional system. However, it was a slightly difference, (40.44 and 40.37, respectively) not being possible to detected visually, what was also previously related in literature (KROLOW et al., 2007).

Organic strawberries showed higher a* value, indicating that strawberries grown in this system exhibit more red external color. This behavior was observed for five of the seven field pairs evaluated (Table 1). However, these results cannot be detect by naked human eye, despite been statistically different. Although the instrumental analysis by colorimeter provides a good relationship between color detected and differences perceived by human evaluators, many times these differences were minimal enough to be not perceived (Cáceres et al., 2016). Crecente-Campo et al. (2012) reported darker red color in strawberries 'Selva' produced by organic system, as well as Reganold et al. (2010) for 'Diamante', 'Lanai' and 'San Juan' strawberries. Nevertheless, Roussos et al. (2012) found no effect for red color between production systems, as wells as no difference between organic and conventionally grown strawberries was observed in most of the studies (CAYELA et al., 1997).

Strawberry firmness is a very important quality parameter (VELICKOVA et al., 2013). In the strawberries case, which are not protected by a hard-outer peel, a little difference in firmness may lead to handling resistance and greater shelf life. In this study, strawberries produced organically were 8.8% (average) firmer than those produced by conventional system were (Tab 1). When each field pair was analyzed separately, this difference reached up to 40.1%, observed in field pair V, where firmness was 7.72 N for organic strawberries and 5.51 N for conventional strawberries, whereas in pair VII fruits from conventional system were 17% firmer than organic fruits (Tab 1). In other previous report, when fruits were produced in similar locations, no effect of production system on strawberry firmness was observed (ROUSSOS et al., 2012). However, Ávila et al. (2012) found higher firmness values in organic 'Camino Real' strawberries (3.84 N) compared to conventional strawberries (3.45 N), while in 'Camarosa' strawberries the difference was bigger, showing 4.77 N for organic and 3,04 N for conventional strawberries.

Soluble solids contents were higher in organic fruits (7.25 ºBrix) than in conventional strawberries (6.10 ºBrix) for five pairs, while, two pairs showed no differences (Tab 1). The largest difference was observed in field pair IV, where organic strawberries showed contents 61.6% higher than conventional strawberries. These findings are similar to previous results reported by Roussos et al. (2012) for strawberries cultivated in integrated and organic managements. Oliveira et al. (2013) showed soluble solid contents were approximately 56% higher for organic fruits compared to conventional fruits. Studies reporting higher values for conventional strawberries when compared to organic fruits are rare (CAMARGO et al., 2011).

Better color, higher firmness and greater soluble solids in organic strawberries are related to fertilization management and nutrient levels, when compared to conventional fruits. Some studies have associated inferior fruit firmness and minor soluble solids contents with high nitrogen dosages applied to strawberries (D'ANNA et al., 2012; EL-SAWY et al., 2012). Nitrogen is beneficial to plant and increases its yields. However, soluble mineral forms or pure manure use can be detrimental for crops, decreasing postharvest transportation resistance, increasing disease incidence, delaying fruit ripening and affecting fruit color. According to Pollan (2008), plants cultivated organically tend to contain added secondary compounds (10 to 50%), which relate to plants defense system to pests and diseases, and contribute to fruit preservation.

No significant differences in weight loss, titratable acidity and ascorbic acid contents were observed between organic and conventional strawberries (Tab 1). Lima et al. (2012) also described no differences in these parameters in strawberries cultivated in different production systems. Weight loss is correlated to water vapor loss, one of the main deterioration causes, resulting not only in quantitative but also in appearance (causing shriveling and wrinkling in fruits), textural (causing softening, loss of coolness and succulence) and in nutritional losses (SPARKS, 2014). Weight losses among 3% and 6% are enough to cause quality reduction in many horticultural crops, while others can lost up to 10% or more with a still good marketable (SPARKS, 2014). Strawberries cultivated in both systems had less than 2.5% of weight loss, indicating that these fruits were appropriate for consumption.

No differences in titratable acidity were observed between organic (0.88%) and conventional strawberries (0.90%) (Table 1). When each field pair was analyzed separately, it was observed that in four pairs organic strawberries showed less acidity and greatest acidity in other three pairs. Lima et al. (2015) found no conclusive differences in titratable acidity among cultivars, regardless production location. These authors studied three strawberry cultivars, and observed higher acidity in organic fruits for one cultivar, lower acidity for another cultivar and no significant differences for the third cultivar.

Ascorbic acid content of organic strawberries (49.07 mg 100 g^{-1}) was not significantly different from conventional strawberries (52.32 mg 100 g^{-1}) (Tab 1). In the same way of titratable acidity, previous results on ascorbic acid content for strawberry from different production systems were not conclusive. Some studies reported higher ascorbic acid contents in organic strawberries, while others reported conventional system provided higher ascorbic acid content for fruits or even, no significant differences between production systems. Vitamin C content depends on many factors, including variety, maturity stage, cultivation conditions and harvest time. These factors may result in considerable variations in results, both between and within studies (SILVA et al., 2013).

Anthocyanin content was higher in conventional strawberries (Tab 1). It was measured 15.18 mg 100 g^{-1} of anthocyanin in conventional strawberries and 13.54 mg 100 g^{-1} for organic strawberries. Higher anthocyanin contents in conventional strawberries were observed in five of the seven field pairs studied. A higher content of anthocyanin in strawberries under conventional farming could be explained by the role of these compounds in diseases prevention and plant protection. This performance can be related by the low rot index verified in these strawberries (Tab 1).

There are few studies in literature clearly determining some influence of agriculture practices on the anthocyanins contents (CRECENTE-CAMPO et al., 2012). Cantillano et al. (2003) observed higher anthocyanin in conventional ‘Camarosa’ and ‘Camino Real’ strawberries. Jin et al. (2011) showed ‘Allstar’ and ‘Earlig’ strawberries produced significantly higher antioxidant capacities and flavonoid contents under organic culture than those produced under conventional production system. In this study, it was found samples from conventional production system had a significantly higher content of anthocyanins.

Rot index was higher in organic fruits than conventional strawberries in five of seven field pairs. The average rot index was 30.16% for organic strawberries and 25.6% for conventional strawberries (Tab 1). A higher rot index for conventional fruits was only observed in field pair IV. The main disease symptoms observed were soft rot caused by *Rhyzopus* spp., gray mold caused by *Botrytis cinerea* and anthracnose caused by *Colletotrichum acutatum* Simmonds. Disease control in conventional strawberry production can be more effective than organic production due to synthetic products employment. However, the chemical products restriction for food security and environmental impact issues has stimulated alternative and biological methods (VALLVERDÚ-QUERALT & LAMUELA-RAVENTÓS, 2015). Ávila et al. (2012) did not find significant differences in disease control between organic and conventional ‘Camino Real’ and ‘Camarosa’ strawberries, indicating potentiality of organic system.

TABLE 1 - Overall average of quality parameters for organic (Org) and conventional (Conv) production systems of strawberries in seven field pairs (I to VII).

System	L*	a*	Firmness	Soluble solids	Weight loss	Titratable acidity	Ascorbic acid	Anthocyanin	Rot index
			N	°Brix	g	----------------	mg 100 g^{-1}	---------------	%
Pair I									
Org	41.72a	22.86b	10.07a	7.28a	2.46a	0.86a	49.35a	11.38b	17.88a
Conv	41.18b	23.36a	7.98b	6.42b	2.47a	0.79b	44.85b	11.61a	21.20a
Pair II									
Org	41.61b	20.36a	7.67a	7.09a	3.47a	0.91a	58.74a	14.28a	28.23a
Conv	42.08a	20.64a	7.33a	5.52b	3.97a	0.78b	56.74b	14.19a	15.64b
Pair III									
Org	42.67a	23.07a	7.07a	6.82a	1.92a	0.72b	50.8b	14.99b	32.00a
Conv	40.37b	20.57b	7.32a	6.45b	2.77a	0.84a	58.67a	20.28a	13.64b
Pair IV									
Org	37.18a	28.50a	6.39a	9.68a	2.84a	1.05a	43.67a	12.32b	34.83b
Conv	38.96a	27.83a	5.56b	5.99b	2.52b	0.96b	43.35a	12.69a	49.49a
Pair V									
Org	39.30a	27.84a	7.72a	7.25a	1.63a	0.74b	26.04b	9.99b	19.51a
Conv	40.52a	26.84b	5.51b	6.05b	1.49b	0.88a	31.92a	10.71a	26.96a
Pair VI									
Org	37.04a	29.97a	5.64a	6.31a	0.82a	0.98b	59.74a	19.83a	46.79a
Conv	36.83a	26.98b	5.73a	6.25a	0.98a	1.09a	64.53a	19.45a	34.00b
Pair VII									
Org	41.11a	25.20a	6.29b	6.18a	2.48a	1.05b	56.92a	14.61b	36.05a
Conv	40.58b	23.28b	7.40a	6.10a	1.90b	1.14a	58.18a	16.09a	26.28b
Overal									
Org	40.44a	24.79a	7.48a	7.25a	2.38a	0.88a	49.07a	13.54b	30.16a
Conv	40.37b	23.48b	6.87b	6.10b	2.43a	0.90a	52.32a	15.18a	25.66b

Averages followed by the same letter within the same column for each field pair are not significantly different according to Tukey test at $p<0.05$.

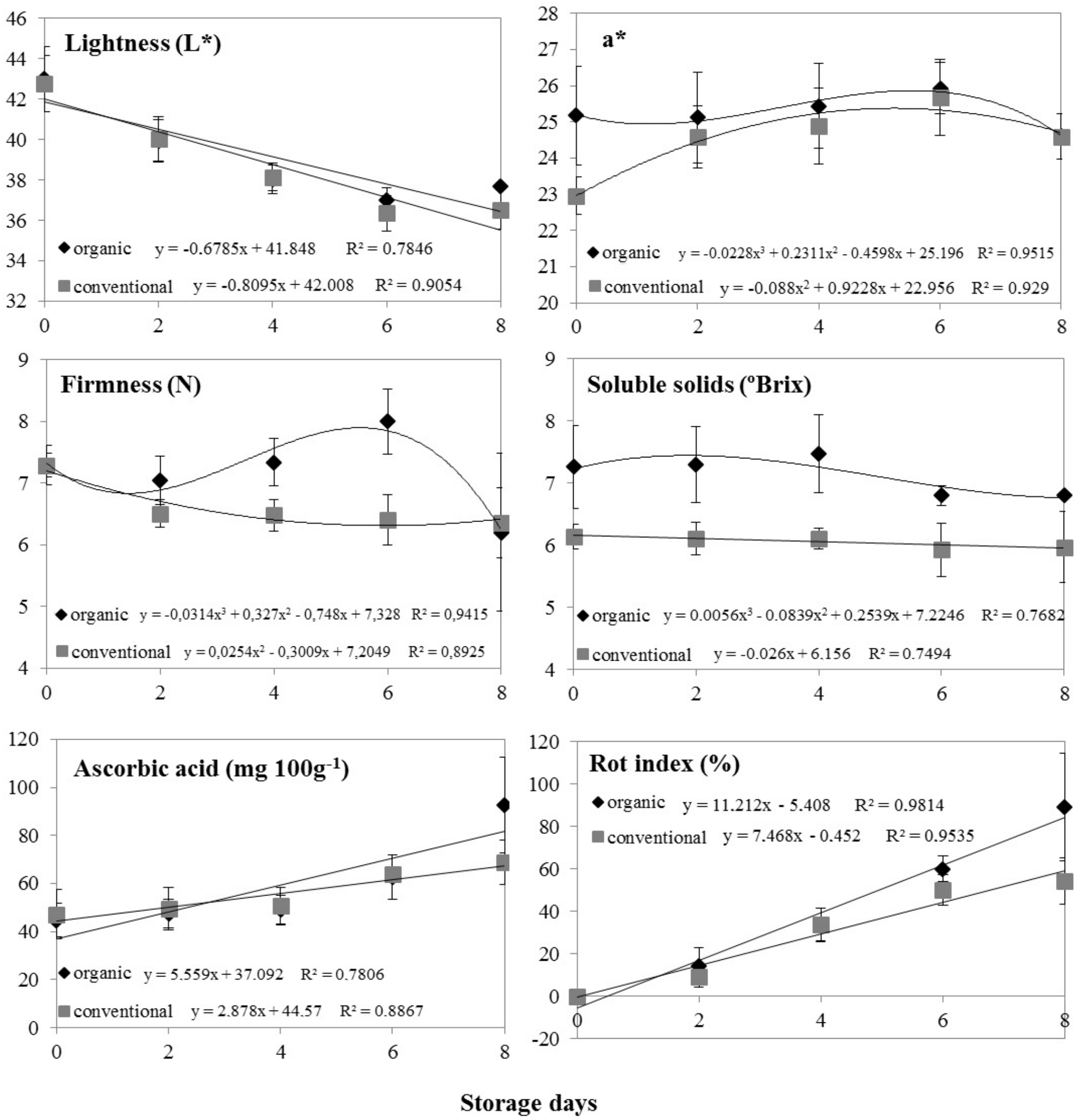

FIGURE 1 – Physical and chemical changes for strawberries cultivated under organic and conventional production systems and stored under refrigeration (15 ± 1 ° C; 90 ± 5% RH) for 8 days. Vertical bars represent mean + standard deviation in each point.

CONCLUSIONS

Strawberries produced under organic production system exhibited higher soluble solids contents and firmer pulp than those produced under conventional system.

Weight loss, titratable acidity and ascorbic acid contents were not influenced by production systems.

Lower rot index was observed in fruits from conventional system, which may be related to soils with minor microbial load due to the use of agrochemicals.

In this work, it was observed that each production system was responsible for contributing differently to quality attributes in strawberries.

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