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CROP PRODUCTION

Influence of genetic variability on the quality of strawberry cultivars: sensorial, physical-chemical and nutritional characterization

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ABSTRACT. Strawberries are berry-type fruits that are very popular and widely consumed all over the world. The sensorial, physical-chemical and nutritional characteristics of strawberries are parameters of quality that influence the choices of consumers. However, these characteristics may be influenced by intrinsic and extrinsic factors that alter the fruit quality. The concentrations of nutrients and other chemical compounds in strawberries may increase and/or decrease according to the cropping system, maturation stage, climatic conditions, and preservation and storage methods. Factors characteristic of the cultivar, such as the genetic profile, may also influence the composition of strawberries. In this context, the objective of this research was to evaluate the sensorial, physical-chemical and nutritional characteristics of different strawberry cultivars to identify the genotype(s) with the best characteristics for commercialization and human consumption. The day-neutral strawberry cultivar "Aromas" and short-day strawberry cultivars "Camarosa, Camino Real, Dover, Sweet Charlie, and Tudla" were cultivated in the Olericultura Sector of the State University of the Midwest (UNICENTRO), Paraná State, Brazil. The fruits were characterized in relation to their physical-chemical, nutritional and sensorial aspects. According to the sensorial profiles, the Camarosa, Camino Real, Dover, and Tudla genotypes showed greater acceptability among consumers. Camarosa, Sweet Charlie, and Tudla presented better physical-chemical characteristics for human consumption, while the cultivars Camarosa, Dover, and Tudla had the best nutritional contents. In general, it is concluded that the genotypes Camarosa and Tudla are the most favourable for human consumption, according to their sensorial, physical-chemical and nutritional characteristics.

Keywords: genotype; acceptability; antioxidants; phytonutrient.

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Introduction

The fruits of the strawberry plant (*Fragaria x ananassa* Duch.) are very popular and widely consumed berries (Paparozzi et al., 2018). World strawberry production has increased by more than 80% in recent decades, reaching more than 9 million tons in 2016. China and the United States stand out among the largest strawberry producers, at 3,801,865 tonnes year^{-1} (141,498 ha) and 1,420,570 tonnes year^{-1} (21,242 ha), respectively. These countries also have the highest gross income relative to strawberry production, varying between US$ 7 billion and US$ 2 billion annually (FAOSTAT, 2016). In Brazil, strawberry productivity was approximately 150,000 tons for an area of 4,200 ha in the period of 2017. The states of Minas Gerais (74,000 tons 2,000 ha^{-1}), Paraná (21,450 tons 650 ha^{-1}), and Rio Grande do Sul (20,350 tons 550 ha^{-1}) are the largest producers of the fruit (Fagherazzi et al., 2017). In 2015, Brazilian sales from strawberry exports totalled US$ 272 million (Antunes, Fagherazzi, & Vignolo, 2017). Fresh strawberries account for 80% of the world production, while the remainder is destined for industrial processing for the preparation of yogurts, jams, jellies and wine (Paparozzi et al., 2018). Considering this aspect, strawberry is one of the most studied genomic and agronomic berries due to its commercial, industrial and economic impacts (Giampieri, Alvarez-Suarez, & Battino, 2014).

The main quality parameters that influence the acceptability of strawberries are the intense red colour, sweet taste and juicy texture of the fruit (Zeliou, Papasotiropoulos, Manoussopoulos, & Lamari, 2018). The flavour of strawberries is determined in particular by the balance between the sweetness of the sugars and the acidity of the organic acids present in its composition. The colour comes from the accumulation of anthocyanins during the maturation process (Boonyakiat, Chuamuangphan, Maniwara, & Seehanam, 2016). In addition to the sensory attributes, strawberries are highly appreciated for their high content of phytochemicals (271 mg 100 g^{-1}) (Fernández-Lara et al., 2015). These substances act as antioxidants in the human body and perform anticarcinogenic (Anwar et al., 2016), antimutagenic (Li et al., 2016), anti-inflammatory (Gasparrini et al., 2017) and antihypertensive (Lajous et al., 2016) functions. Another relevant nutritional aspect of strawberries is their high content of vitamin C (90,13 mg 100 g^{-1}) (Souza et al., 2014). In the human body, vitamin C helps in the treatment of diabetes mellitus (Shivavedi, Kumar, Tej, & Nayak, 2017), improves immune function (Bozonet, Carr, Pullar, & Vissers, 2015) and acts as a retarding factor in the development of leukaemia (Agathocleous et al., 2017). Thus, strawberries stand out among red berries for their potential health benefits as well as their qualitative and quantitative characteristics (Giampieri et al., 2015), which require periodic evaluations.

Although they have a favourable chemical, nutritional and sensorial profile, strawberries can suffer interference from intrinsic and extrinsic factors that alter its characteristics. Evidence has already suggested that the concentration of nutrients and compounds in strawberries can increase and/or decrease according to the cultivation system (Abountiolas et al., 2018), stage of maturation (Boonyakiat, Chuamuangphan, Maniwara, & Seehanam, 2016), climate conditions (Akhtar& Rab, 2015), preservation methods (Ergin, Yaman, & Dilek, 2018) and storage methods (Maksimović et al., 2015). Factors characteristic of the cultivar, such as the genetic profile, may also influence strawberry composition, as already demonstrated in the literature. The Monterey cultivar, for example, presented higher contents of phenolic compounds and anthocyanins than the cultivars Albion, Capri and Murano (Šamec et al., 2016). The cultivar Sabrina had greater sensorial acceptability than Fortuna and Camarosa (Zeliou, Papasotiropoulos, Manoussopoulos, & Lamari, 2018). In this context, the objective of this research was to evaluate the sensorial, physical-chemical and nutritional characteristics of different strawberry cultivars to identify the genotype(s) with the best characteristics for commercialization and human consumption.

Material and methods

Plant material and cultivation technique

The day-neutral strawberry cultivar (*Fragaria x ananassa* Duch.) "Aromas" and short-day cultivars "Camarosa, Camino Real, Dover, Sweet Charlie, and Tudla" (Figure 1) were cultivated in the Olericultura Sector of the State University of the Midwest (UNICENTRO) of the municipality of Guarapuava (25°23'28.9"S 51°27'42.5" W, with an altitude of 1,116.5 m), Paraná State, Brazil. Seed germination was carried out in a chapel-type agricultural stove (276 m^2 with a right foot of 3.5 m) with a clear plastic cover 150 microns in thickness. The seedlings were transplanted to an open field with a low tunnel system. The planting depth of the seedlings was sufficient to leave the crown exposed superficially. The experimental design was a randomized block with 3 replicates. The strawberries were harvested in November 2017 at the end of the ripening period (> 75% of the red surface). The berries were separated to remove damaged, withered and green fruits. Three hours after harvesting, approximately 1 kg of each cultivar was placed in storage at -20°C and stored for 30 days for further analysis of the quality parameters. For sensory evaluation, approximately 70 whole fruits of each cultivar were stored at 4°C and evaluated the day after harvest.

Figure 1. Strawberry cultivars evaluated.

Sampling and processing

The strawberries were thawed in a refrigerator (Electrolux®, DC35A, Brazil) at 4°C for 24 hours. The pulp was then homogenized in a household grinder (Britânia®, Black Plus, Brazil) for approximately 1 minute. For the analyses, approximately 300 g of pulp was used from each cultivar.

Sensory evaluation

Sensory evaluation was performed with 60 untrained adult consumers (18 to 59 years) of both genders, recruited from academics and UNICENTRO employees in Guarapuava, Paraná State, Brazil. The attributes of appearance, aroma, flavour, texture and colour were evaluated, in addition to global acceptance, through a structured hedonic scale of 9 points, varying from "very disagreeable" (note 1) to "liked very much" (note 9). An intention of purchase test was also applied, using a 5-point scale ranging from "certainly buy" (note 5) and "certainly would not buy" (note 1) (Meilgaard, Civille, & Carr, 2015). The judges received two samples of each cultivar (approximately 15 g) in white plastic cups encoded with 3-digit numbers in a balanced and randomized manner (Macfie & Bratchell, 1989); the judges were provided with water for cleansing the palate. Samples were offered to the judges in sequential monadic form (Macfie & Bratchell, 1989). The acceptability index (IA) was calculated according to the following equation: *IA (%) = A x 100/B* (*A* = average score obtained for the sample; *B* = maximum grade given to the sample) (Guimarães, Vendramini, Santos, Leite, & Miguel, 2013).

Physical-chemical composition

The following physical-chemical parameters were measured in fresh strawberries in triplicate and expressed on a wet basis: *pH*, obtained by direct reading with a bench pH meter (Tecnopon®, Mpa-210, Brazil); *water activity* (Aw), measured by direct measurement with an Aw analyser (Novasina®, Labswift, Switzerland) at 13°C; *soluble solids* (SS) (°Brix), determined by direct reading with a calibrated optical refractometer (Optech®, RMT, Canada); *titratable acidity* (TA), titrated using a standard 0.1 M NaOH solution to a pH of 8.2 (IAL, 2005). The results were expressed as % citric acid per 100 g fresh weight (%); *SS/TA ratio,* obtained by dividing the SS readings and TA results; *total sugar* (TS) and *reducing sugar* (RS) contents, determined by the Lane-Eynon method (Association of Official Analitical Chemists [AOAC], 2000); *non-reducing sugar* (NRS) content, calculated as the difference between the TS and RS; *colour,* measured directly from the surface of the fresh fruits. The system of the Commission Internatinale de E'clairage (CIE) *L**, *a**, *b** was used for the colorimetry readings by means of a previously calibrated colorimeter (Konica Minolta®, Chroma Meter CR 4400, Japan) with illuminant D65 and an angle of 10°. The parameters analysed were *L** (luminosity), *a** (red-green) and *b** (yellow-blue) in addition to the values for chroma (vivacity-opacity) and hue (hue); and *antioxidant capacity* (μmol Trolox 100 g^{-1}), which includes hydrophilic and lipophilic antioxidants, determined using 2.20-azinobis-(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) (Miller & Rice-Evans, 1997). The samples were analysed at 734 nm in a spectrophotometer (Agilent Technologies®, Cary 60 UV, Malaysia).

Nutritional composition

The fruits were analysed in triplicate in relation to *moisture content* (g 100 g^{-1}), determined by the mass difference after drying in an oven at 105°C to a constant weight (AOAC, 2016); *amount of ash* (g 100 g^{-1}), calculated by the weight difference after incineration of the samples in a muffle furnace with a microprocessor (Tecnal®, 3000-10P, Brazil) at 600°C (AOAC, 2016); *protein content* (g 100 g^{-1}), estimated by the total nitrogen content of the sample measured according to the Micro-Kjeldahl method and calculated using the total nitrogen conversion factor 6.25 (AOAC, 2016); *lipid content* (g 100 g^{-1}), determined by the cold extraction method (Bligh & Dyer, 1959); *carbohydrate content* (g 100 g^{-1}), evaluated by theoretical calculation (by difference) according to the formula: *% Carbohydrate = 100 – (% moisture + % protein + % lipid + % ash + % dietary fibre)* (Raghuramulu, Madhavan, & Kalyanasundaram, 2003); *total caloric value* (kcal), calculated using the following values: lipid (8.93 kcal g^{-1}), protein (4.27 kcal g^{-1}) and carbohydrate (3.82 kcal g^{-1}) (Merrill & Watt, 1973); *ascorbic acid content* (mg 100 g^{-1}), evaluated by a titration method with 2,6-dichlorophenol-indophenol (DCFI) (AOAC, 1984); *total phenolic compound content* (mg GAE 100 g^{-1}), determined by the Follin-Ciocauteau method in a spectrophotometer (Agilent Technologies®, Cary 60 UV, Malaysia) at 740 nm (Bucic-Kojic, Planinic, Srecko, Bilic, & Velic, 2007); and *total anthocyanin content* (mg CGE 100 g^{-1}), quantified by the differential pH method (Giusti & Wrosltad 2001). The absorbance was measured at 504.5 nm and 700 nm in a spectrophotometer (Agilent Technologies®, Cary 60 UV, Malaysia) in a potassium chloride buffer (0.025 M, pH 1.0) and sodium acetate (0.4 M, pH 4.5). All the analyses were expressed on a wet basis.

Ethical issues

The research was approved by the Research Ethics Committee of UNICENTRO, opinion No. 2,201,325/2017. To participate in the sensory analysis, the individuals signed the Free and Informed Consent Form and participated voluntarily through an invitation from the researchers in which all the steps and objectives were explained to the participants.

The inclusion criteria required adult individuals aged 18 years or older and 59 years or younger. Individuals younger than 18 or older than 59 years, pregnant individuals and individuals with strawberry allergies or who did not routinely consume the fruit were excluded.

Statistical analysis

The results were subjected to one-way ANOVA, using Tukey's test to compare the means. All the tests were analysed at a 5% level of significance using the IBM SPSS Statistics® version 17 software.

Results and discussion

Sensory evaluation

The sensory profile of the strawberry cultivars is described in Table 1. Higher scores for appearance and colour ($p < 0.05$) were attributed to the cultivars Camarosa, Dover, and Tudla, while Aromas and Sweet Charlie presented lower scores. There were no differences ($p > 0.05$) in the acceptability of the strawberries in the aroma and texture attributes, the overall acceptance or the purchase intent. The cultivar Camino Real was awarded a significantly higher flavour score than Aromas and Camarosa. The remaining fruits did not differ in flavour score ($p > 0.05$). Similar results have been reported in other studies evaluating genotypes from Brazil (Antunes, Cuquel, Zawadneak, Mogor, & Resende, 2014) and from Greece (Zeliou et al., 2018). Regarding the purchase of strawberries, attributes such as colour and appearance have greater consumer impact than other attributes because they are the first attributes to be evaluated (Fernández-Lara et al., 2015). Research has already demonstrated that the appearance/colour of strawberries positively influences the fruit flavour (Maksimović et al., 2015; Tahir et al., 2018). Maksimović et al. (2015) evaluated the sensory characteristics of 8 strawberry genotypes (Daroyal, Honeoye, Elsanta, Figaro, Sonata, Salsa, Florence, and Symphony) cultivated in Serbia. The highest notes for flavour were attributed to cultivars with better appearance. In strawberries treated with an edible coating based on gum arabic, the acceptability was higher ($p < 0.05$) than that for uncoated fruit (Tahir et al., 2018). This process was able to highlight the colour and brightness of strawberries, increasing scores for appearance and flavour, although the coated and uncoated fruits had similar physical-chemical and nutritional characteristics. In the present research, the positive effect of appearance on acceptability was confirmed for the cultivars Dover and Tudla and did not occur for Camarosa, Camino Real or Sweet Charlie. The cultivars presented AI ⩾ 70% for all sensory parameters (Corradini et al., 2014). These results demonstrate that strawberries have good sensory acceptance (Šamec et al., 2016), regardless of the type of cultivar. However, considering the sensory profile of strawberries, it can be observed that, in general, the Camarosa, Camino Real, Dover, and Tudla genotypes are more acceptable to consumers.

Table 1. Sensorial scores (mean ± standard deviation) and acceptability index (AI) of strawberries cultivars.

Parameter	Aromas	Camarosa	Camino Real	Dover	Sweet Charlie	Tudla
Appearance	7.68 ± 1.05^{c}	8.25 ± 0.86^{ab}	7.77 ± 1.12^{bc}	8.30 ± 0.77^{a}	7.65 ± 0.95^{c}	8.05 ± 0.93^{abc}
AI (%)	85.37	91.67	86.30	92.22	85.00	89.44
Aroma	7.27 ± 1.60^{a}	8.00 ± 1.04^{a}	7.82 ± 1.11^{a}	7.45 ± 1.47^{a}	7.50 ± 1.59^{a}	7.60 ± 1.51^{a}
AI (%)	80.74	88.89	86.85	82.78	83.33	84.44
Flavour	7.02 ± 1.44^{b}	7.13 ± 1.23^{b}	7.90 ± 0.86^{a}	7.20 ± 1.70^{ab}	7.30 ± 1.73^{ab}	7.72 ± 1.11^{ab}
AI (%)	77.96	79.26	87.78	80.00	81.11	85.74
Texture	7.62 ± 1.44^{a}	7.83 ± 1.22^{a}	7.68 ± 1.25^{a}	7.62 ± 1.39^{a}	7.50 ± 1.53^{a}	7.55 ± 1.18^{a}
AI (%)	84.63	87.04	85.37	84.63	83.33	83.89
Colour	7.73 ± 1.20^{b}	8.30 ± 0.91^{ab}	7.80 ± 1.37^{ab}	8.35 ± 0.80^{a}	7.70 ± 1.57^{b}	8.10 ± 0.84^{ab}
AI (%)	85.93	92.22	86.67	92.78	85.56	90.00
Global Acceptance	7.25 ± 1.46^{a}	7.77 ± 1.20^{a}	7.67 ± 0.17^{a}	7.27 ± 1.51^{a}	7.27 ± 1.41^{a}	7.12 ± 1.46^{a}
AI (%)	80.56	86.30	85.19	80.74	80.74	79.07
Purchase Intent	4.20 ± 0.95^{a}	4.43 ± 1.01^{a}	4.38 ± 0.92^{a}	3.92 ± 1.18^{a}	4.05 ± 1.16^{a}	3.95 ± 1.18^{a}

Different letters in a row indicate a significant difference by Tukey's test ($p < 0.05$).

Physical-chemical composition

The physical-chemical compositions of the strawberry cultivars are described in Table 2. The genetic profile was associated with changes ($p < 0.05$) in the pH value of the fruits. The highest pH value was observed in the Tudla cultivar, in contrast to those found for Aromas and Camarosa, which were the lowest with no difference between them ($p > 0.05$). The A_w values did not differ significantly between cultivars. Dermesonlouoglou et al. (2017) observed similar results for pH (3.49) and A_w (0.95) in the Camarosa cultivar from Greece. Strawberry is a naturally acidic fruit (pH < 6) due to the presence of organic acids, which may vary according to the type of cultivar (Liu et al., 2016). Strawberries with less acidic pH (> 3) are sensorially better accepted because they have low acidity (Oliveira et al., 2015), as verified in this research. Despite the variation in the pH and TA values, all the cultivars had good global acceptance (Table 1). From the genetic point of view, the type of cultivar has little or no influence on A_w (Dermesonlouoglou et al., 2017), since strawberries are composed of 95% water (Bovi et al., 2018).

The levels of SS and TA varied ($p < 0.05$) between cultivars. The cultivar Tudla had the highest SS content, while Aromas and Dover had the lowest concentrations, not differing from each other ($p > 0.05$). The highest TA content ($p < 0.05$) was found in Camarosa (1.42 g AC 100 g^{-1}) and the lowest in Camino Real (0.97 g AC 100 g^{-1}). The Camino Real genotype was distinguished by a higher SS/TA ratio, while Aromas and Camarosa had the lowest proportions. Results similar to these evaluations were observed by Šamec et al. (2016) in Albion, Capri, Murano, and Monterey genotypes grown in Croatia. In strawberries, the SS content indicates the amount of solids such as sugars, vitamins, amino acids and pectin dissolved in the fruit pulp, while TA represents the acid concentration (Akhatou & Fernándes-Recamales, 2013). The balance between SS/TA is associated with fruit flavour (Liu et al., 2016), as verified in the present study. The cultivar Camino Real presented the highest SS/TA ratio and consequently a more palatable taste (Table 1). Lower scores for this attribute were attributed to the cultivars Aromas and Camarosa due to their low SS/TA ratios. The concentrations of SS and TA in strawberries are related to the reactions of the cultivar with external factors. Some genotypes, for example, are more sensitive to elevated temperatures (> 25°C) during cultivation. This factor can increase the respiratory rate of the fruit, which reduces the SS content and increases TA (Liu et al., 2016).

The strawberry cultivars differed ($p < 0.05$) in relation to the sugar concentration (Table 2). The highest TS content was observed in the Tudla cultivar, with no difference ($p > 0.05$) between Aromas and Camarosa, which presented the lowest percentages. The Tudla cultivar also presented a higher concentration of RS ($p < 0.05$), while those of Camino Real and Sweet Charlie were lower ($p > 0.05$). The NRS content was higher in Camino Real, while those of Aromas and Camarosa were lower and did not differ from each other ($p > 0.05$). Similar results were reported for the cultivar Chandler at different irrigation intervals (4 to 14 days) (Akhtar & Rab, 2015). In contrast, the same cultivar produced in India presented levels of TS and RS (Muzzaffar et al., 2016), which were lower than those observed in the present study. In strawberries, the sugars are synthesized during the photosynthetic process (Akhtar & Rab, 2015). In stress conditions or in the post-harvest period, these substances are used as energy sources for the metabolic and respiratory processes of the fruit (Muzzaffar et al., 2016). Thus, the sugar content in the fruit, as well as the levels of SS and TA, varies according to the response of each cultivar to the macro or microenvironmental conditions during maturation and ripening (Perla et al., 2016). Sugars can also be used as a parameter of sensory quality in strawberries because sugars are converted to aromatic compounds such as esters, terpenoids and furanones (Akhatou & Fernández-Recamales, 2014). Despite this fact, the differences in the sugar contents of the cultivars did not interfere with the affective scores for the aroma (Table 1).

The colour parameters L^*, a^*, b^*, chroma and hue differed significantly among the genotypes (Table 2). The cultivars Tudla and Camarosa showed high luminosity (L^*), while the lowest percentage was found in Dover. The cultivars Dover, Sweet Charlie and Tudla had a higher red content (a^*) ($p < 0.05$) than Camino Real. Higher yellow (b^*) content was observed for Camarosa, Sweet Charlie and Tudla. The value of chroma was higher for the Sweet Charlie cultivar than for Aromas and Camino Real, while Camarosa and Sweet Charlie showed higher values for hue than the Dover genotype. Other cultivars produced in Mexico (Fernández-Lara et al., 2015) obtained results for instrumental colour very close to those of the present research. In general, strawberries can be considered to be dark in colour, since all the values for L^* were lower than 50%, with shades of red (a^*) and subtones of yellow (b^*) (Peretto et al., 2014). In addition, the strawberries stand out for their brightness (values of chroma closer to 60) and red hues (hue values closer to 0) (Fadda et al., 2015). According to Boonyakiat et al. (2016), an increase in the concentration of anthocyanins reduces the luminosity at the surface of the fruits and increases the values of chroma, which was suggested in this research.

Table 2. Mean physical-chemical compositions (± standard deviation) of strawberry cultivars.

Parameter	Aromas	Camarosa	Camino Real	Dover	Sweet Charlie	Tudla
pH	3.44 ± 0.01[c]	3.40 ± 0.00[c]	3.57 ± 0.06[b]	3.57 ± 0.01[b]	3.52 ± 0.01[b]	3.72 ± 0.11[a]
Water activity	0.98 ± 0.00[a]	0.98 ± 0.00[a]	0.98 ± 0.00[a]	0.98 ± 0.00[a]	0.98 ± 0.00[a]	0.97 ± 0.00[a]
Soluble Solids (°Brix)	6.42 ± 0.14[d]	7.58 ± 0.14[c]	7.50 ± 0.00[c]	6.50 ± 0.00[d]	8.25 ± 0.00[b]	8.92 ± 0.14[a]
Titratable Acidity (g AC 100 g^{-1})	1.19 ± 0.01[c]	1.42 ± 0.01[a]	0.97 ± 0.01[e]	1.02 ± 0.01[d]	1.20 ± 0.01[bc]	1.22 ± 0.01[b]
Soluble solids/Titratable Acidity	5.39 ± 0.09[e]	5.35 ± 0.15[e]	7.73 ± 0.07[a]	6.36 ± 0.04[d]	6.85 ± 0.04[c]	7.28 ± 0.16[b]
Total Sugars (%)	6.60 ± 0.08[d]	6.69 ± 0.05[d]	7.65 ± 0.07[b]	7.12 ± 0.04[c]	7.23 ± 0.03[c]	10.07 ± 0.02[a]
Reducing sugars (%)	6.11 ± 0.04[c]	6.07 ± 0.02[c]	5.55 ± 0.03[d]	6.29 ± 0.04[b]	5.57 ± 0.04[d]	9.12 ± 0.05[a]
Non-Reducing Sugars (%)	0.49 ± 0.04[d]	0.62 ± 0.03[d]	2.10 ± 0.09[a]	0.83 ± 0.08[c]	1.65 ± 0.07[b]	0.96 ± 0.05[c]
*L**	31.80 ± 0.37[c]	34.00 ± 0.32[ab]	28.00 ± 0.00[d]	26.40 ± 0.24[e]	33.40 ± 0.51[b]	35.40 ± 0.40[a]
*a**	32.60 ± 0.81[ab]	32.20 ± 0.73[ab]	30.00 ± 0.32[b]	33.60 ± 0.51[a]	35.20 ± 1.11[a]	34.60 ± 0.40[a]
*b**	14.20 ± 0.58[c]	20.80 ± 0.49[a]	17.00 ± 0.32[b]	12.80 ± 0.37[c]	21.60 ± 0.93[a]	20.20 ± 0.37[a]
Chroma	35.60 ± 0.87[b]	38.60 ± 0.98[ab]	34.60 ± 0.40[b]	36.20 ± 0.49[ab]	41.20 ± 1.50[a]	38.20 ± 1.88[ab]
Hue	23.60 ± 0.68[c]	32.60 ± 0.24[a]	29.60 ± 0.24[b]	21.40 ± 0.24[d]	31.40 ± 0.68[ab]	30.00 ± 0.45[b]

Different letters in a row indicate a significant difference by Tukey's test ($p < 0.05$). The results are expressed on a wet basis.

The antioxidant capacity presented little variability among the genotypes (Figure 2). The antioxidant potential of the hydrophilic fraction was higher ($p < 0.05$) in Dover and lower in Camarosa. Conversely, Dover showed the lowest antioxidant capacity through the lipophilic fraction, while Sweet Charlie demonstrated the highest potential. Lower results were observed for Magic and Premial cultivars produced in Romania (Nour, Trandafir, & Cosmulescu, 2017) and for Camarosa, Sabrina, and Fortuna cultivated in Greece (Zeliou et al., 2018). In strawberries, the main hydrophilic antioxidant substances are vitamin C and phenolic compounds. Carotenoids and vitamin E are classified as lipophilic antioxidants (Hernández et al., 2017). Thus, it was observed that cultivars with higher concentrations of vitamin C and phenolic compounds (Table 3) also had higher hydrophilic antioxidant capacities (Figure 2). This result proves that the genetic profile is a factor that directly influences the synthesis of bioactive compounds and the antioxidant capacity. Strawberry is considered a functional food because of its potential health benefits (Skrovankova, Sumczynski, Mlcek, Jurikova, & Sochor, 2015), especially since it has high antioxidant capacity (Souza et al., 2014). In this context, the cultivars Camarosa, Sweet Charlie, and Tudla presented better physical-chemical characteristics for human consumption, while the reverse was observed in Aromas, Camino Real, and Dover.

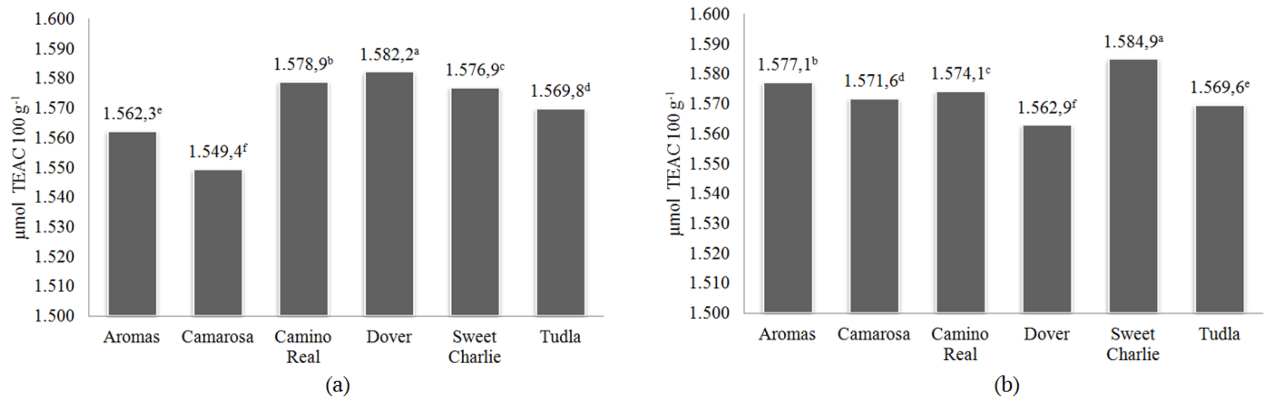

Figure 2. Hydrophilic (a) and lipophilic (b) antioxidant capacity of strawberry cultivars. Different letters indicate a significant difference by Tukey's test ($p < 0.05$).

Nutritional composition

Table 3 shows the evaluation of the nutritional composition of the strawberry cultivars, which showed little variation. The fruits presented high moisture content, with higher percentages for Aromas, Camino Real and Sweet Charlie. Camarosa, Dover, and Tudla had lower moisture contents ($p < 0.05$). High moisture content in strawberries is associated with the fruit's capacity to expand, which increases water absorption during the irrigation process (Akhtar & Rab 2015), a fact that reduces the shelf-life of the strawberry (Okut et al., 2018). The ash values of the cultivars ranged from 0.32 g 100 g^{-1} (Camino Real) to 0.46 g 100 g^{-1}

(Tudla). All the cultivars presented low levels of proteins (0.49 g 100 g^{-1} to 0.74 g 100 g^{-1}), lipids (0.16 g 100 g^{-1} to 0.23 g 100 g^{-1}), carbohydrates (7.13 g 100 g^{-1} to 8.93 g 100 g^{-1}) and calories (30.81 kcal 100 g^{-1} at 38.62 kcal 100 g^{-1}). However, higher concentrations of proteins, lipids, carbohydrates and calories were observed for Camarosa and Dover. These results are similar to those for other strawberry genotypes (FA 01, FA 02, FA 03, and FA 06) cultivated in Bangladesh (Hossain et al., 2016).

Table 3. Nutritional composition (± standard deviation) of strawberry cultivars.

Parameter	Aromas	Camarosa	Camino Real	Dover	Sweet Charlie	Tudla
Moisture (g 100 g^{-1})	91.73 ± 0.09^a	90.04 ± 0.07^b	91.83 ± 0.11^a	89.84 ± 0.03^b	91.84 ± 0.15^a	89.81 ± 0.19^b
Ash (g 100 g^{-1})	0.36 ± 0.00^c	0.44 ± 0.00^b	0.32 ± 0.01^d	0.44 ± 0.01^b	0.36 ± 0.01^c	0.46 ± 0.00^a
Protein (g 100 g^{-1})	0.52 ± 0.01^c	0.72 ± 0.02^a	0.49 ± 0.01^c	0.74 ± 0.00^a	0.49 ± 0.01^c	0.57 ± 0.00^b
Lipid (g 100 g^{-1})	0.17 ± 0.02^b	0.23 ± 0.14^a	0.16 ± 0.00^b	0.23 ± 0.00^a	0.16 ± 0.00^b	0.22 ± 0.01^a
Carbohydrate (g 100 g^{-1})	7.16 ± 0.07^b	8.53 ± 0.21^a	7.13 ± 0.03^b	8.74 ± 0.05^a	7.15 ± 0.16^b	8.93 ± 0.18^a
Total caloric value (kcal 100 g^{-1})	31.16 ± 0.15^b	37.80 ± 0.13^a	30.81 ± 0.10^b	38.62 ± 0.18^a	30.82 ± 0.62^b	38.61 ± 0.82^a
Ascorbic acid (mg 100 g^{-1})	21.22 ± 0.00^e	19.91 ± 0.11^f	37.64 ± 0.04^a	22.86 ± 0.06^d	35.77 ± 0.11^b	25.07 ± 0.11^c
Phenolic compounds (mg GAE 100 g^{-1})	209.52 ± 0.05^b	164.55 ± 0.07^d	140.38 ± 0.05^e	112.84 ± 0.12^f	203.22 ± 0.10^c	230.15 ± 0.12^a
Anthocyanin (mg CGE 100 g^{-1})	18.36 ± 0.08^f	23.36 ± 0.09^b	22.64 ± 0.09^d	24.90 ± 0.12^a	21.07 ± 0.12^e	23.00 ± 0.12^c

Different letters in the row indicate a significant difference by the Tukey test ($p < 0.05$). Results expressed as wet basis.

The concentrations of ascorbic acid, phenolic compounds and anthocyanins were different among the cultivars (Table 3). The ascorbic acid content ranged from 19.91 mg 100 g^{-1} (Camarosa) to 37.64 mg 100 g^{-1} (Camino Real). These results corroborate those of Maksimović et al. (2015), who studied strawberry genotypes (Daroyal, Honeoye, Elsanta, Sonata, Figaro, Salsa, Florence, and Symphony) grown in Serbia. The content of phenolic compounds was higher in the cultivar Tudla (230.15 mg GAE 100 g^{-1}) than in Dover (112.84 mg GAE 100 g^{-1}). The cultivar Dover (24.90 mg CGE 100 g^{-1}) had the highest concentration of anthocyanins, while Aromas (18.36 mg CGE 100 g^{-1}) presented the lowest value. These findings are in agreement with other studies that evaluated strawberries (Magic and Premial) cultivated in Romania (Nour et al., 2017) and in Croatia (Albion, Capri, Murano and Monterey) (Šamec et al., 2016). In strawberries, phytochemicals act as protective agents against the action of pathogens (Nour et al., 2017). The morphological characteristics of strawberry leaves may also influence the phytochemical contents. Cultivars with more developed leaves may block the incidence of sunlight in some parts of the fruit, which reduces the synthesis of bioactive substances in strawberries (Pátkai, 2012). Compounds such as ascorbic acid are synthesized in the fruit from reducing sugars such as glucose and galactose. Thus, strawberries with high levels of ascorbic acid tend to present low levels of RS (Perla et al., 2016), which was indicated in this study (Table 2). In the human body, phytochemicals act as antioxidants, protecting cells from the action of free radicals (Giampieri et al., 2017). These substances perform anticarcinogenic (Li et al., 2016), anti-inflammatory (Gasparrini et al., 2017), anti ageing (Rendeiro, Rhodes, & Spencer, 2015) and antihypertensive (Lajous et al., 2016) functions. According to the nutritional characteristics, the cultivars Camarosa, Dover, and Tudla presented more favourable profiles for human consumption, while Aromas, Camino Real, and Sweet Charlie were less favourable cultivars in this respect.

Conclusion

It is concluded that the cultivars Camarosa and Tudla present the most favourable sensorial, physicochemical and nutritional characteristics for human consumption and are more suitable for commercialization.

References

Abountiolas, M., Kelly, K., Yagiz, Y., Li, Z., Mahnken, G., Borejsza, W., Marshall, M.R., ... Nascimento, D. (2018). Sensory quality, physicochemical attributes, polyphenol profiles and residual fungicides in strawberries from different disease control treatments. *Journal of Agricultural and Food Chemistry*, *66*(27), 6986-6996. DOI: 10.1021/acs.jafc.8b02153

Agathocleous, A., Meacham, C. E., Burgess, R. J., Piskounova, E., Zhao, Z., Crane, G. M., DeBerardinis, R. J., & Morrison, S. J. (2017). Ascorbate regulates haematopoietic stem cell function and leukaemogenesis. *Nature*, *549*(7673), 476-481. DOI: 10.1038/nature23876

Akhatou, I., & Fernándes-Recamales, Á. F. (2013). Influence of cultivar and culture system on nutritional and organoleptic quality of strawberry. *Journal of the Science of Food and Agriculture*, *94*(1), 866-875. DOI: 10.1002/jsfa.6313

Akhatou, I., & Fernández-Recamales, Á. (2014). Nutritional and nutraceutical quality of strawberries in relation to harvest time and crop conditions. *Journal of Agricultural and Food Chemistry*, *62*(25), 5749-5760. DOI: 10.1021/jf500769x

Akhtar, I., & Rab, A. (2015). Effect of irrigation intervals on the quality and storage performance of strawberry fruit. *Journal of Animal & Plant Sciences*, *25*(3), 669-678.

Antunes, L. E., Fagherazzi, A. F., & Vignolo, G. K. (2017). Morangos tem produção crescente. *Campo & Lavoura*, *1*(1), 96-102.

Antunes, M. C., Cuquel, F. L., Zawadneak, M. A. C., Mogor, Á. F., & Resende, J. T. V. (2014). Postharvest quality of strawberry produced during two consecutive seasons. *Horticultura Brasileira*, *32*(2), 168-173. DOI: 10.1590/S0102-05362014000200008

Anwar, S., Fratantonio, D., Ferrari, D., Saija, A., Cimino, F., & Speciale, A. (2016). Berry anthocyanins reduce proliferation of human colourectal carcinoma cells by inducing caspase-3 activation and p21 upregulation. *Molecular Medicine Reports*, *14*(2), 1397-1403. DOI: 10.3892/mmr.2016.5397

Association of Official Analitical Chemists [AOAC]. (1984). *Official methods of analisys of AOAC International*. Gaithersburg, US: AOAC.

Association of Official Analitical Chemists [AOAC]. (2000). *Official Method 925.35 Sucrose in fruits and fruit products read with AOAC official method 923.09. Lane and Eynon general volumetric method* (17th ed.). Gaithersburg, US: AOAC.

Association of Official Analitical Chemists [AOAC]. (2016). *Official Methods of Analysis of AOAC International*. Gaithersburg, US: AOAC International.

Bligh, E. G., & Dyer, W. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal Biochemistry and Physiology*, *37*(8), 911-917.

Boonyakiat, D., Chuamuangphan, C., Maniwara, P., & Seehanam, P. (2016). Comparison of physical-chemical quality of different strawberry cultivars at three maturity stages. *International Food Research Journal*, *23*(6), 2405-2412.

Bovi, G. G., Caleb, O. J., Klaus, E., Tintchev, F., Rauh, C., & Magajan, P. V. (2018). Moisture absorption kinetics of FruitPad for packaging of fresh strawberry. *Journal of Food Engineering*, *223*(1), 248-254. DOI: 10.1016/j.jfoodeng.2017.10.012

Bozonet, S. M., Carr, A. C., Pullar, J. M., & Vissers, M. (2015). Enhanced human neutrophil vitamin c status, chemotaxis and oxidant generation following dietary supplementation with vitamin c-rich sungold kiwifruit. *Nutrients*, *7*(4), 2574-2588. DOI: 10.3390/nu7042574

Bucic-Kojic, A., Planinic, M., Srecko, T., Bilic, M., & Velic, D. (2007). Study of solid–liquid extraction kinetics of total polyphenols from grape seeds. *Journal of Food Engineering*, *81*(1), 236-242. DOI: 10.1016/j.jfoodeng.2006.10.027

Corradini, S. A. S., Madrona, G. S., Visentainer, J. V., Bonafe, E. G., Carvalho, C. B., Roche, P. M., & Prado, I. (2014). Sensorial and fatty acid profile of ice cream manufactured with milk of crossbred cows fed palm oil and coconut fat. *Journal of Dairy Science*, *97*(11), 6745-6753. DOI: 10.3168/jds.2014-8290

Dermesonlouoglou, E. K., Bimpilas, A., Andreou, V., Katsaros, G. J., Giannakourou, M. C., & Taoukis, P. S. (2017). Process optimization and kinetic modeling of quality of fresh-cut strawberry cubes pretreated by high pressure and osmosis. *Journal of Food Processing and Preservation*, *41*(5), 1-14. DOI: 10.1111/jfpp.13137

Ergin, S. O., Yaman, H., & Dilek, M. (2018). The usage of edible films extracted from cherry and apricot tree gums for coating of strawberry (*Fragaria ananassa*) and loquat (*Eriobotrya japonica*) fruits. *Food Science and Technology*, *6*(5), 561-569. DOI: 10.24925/turjaf.v6i5.561-569.1768

Fadda, C., Antonio, P., Fenu, M., Usai, G., Caro, A. Del, Diez, Y. M., … Piga, A. (2015). Antioxidant activity and sensory changes of strawberry tree fruits during cold storage and shelf life. *Czech Journal of Food Sciences*, *33*(6), 531-536. DOI: 10.17221/171/2015-CJFS

Fagherazzi, A. F., Grimaldi, F., Kretzschmar, A. A., Molina, A. R., Gonçalves, M. A., Antunes, L. E. C., … Rufato, L. (2017). Strawberry production progress in Brazil. *Acta Horticulturae*, *1156*(1156), 937-940. DOI: 10.17660/ActaHortic.2017.1156.138

FAOSTAT. (2016). *World production of strawberries*. Retrieved on July 1, 2017, from http://www.fao.org/faostat/en/#data

Fernández-Lara, R., Gordillo, B., Rodríguez-Pulido, F. J., Lourdes González-Miret, M., del Villar-Martínez, A. A., Dávila-Ortiz, G., & Heredia, F. J. (2015). Assessment of the differences in the phenolic composition and colour characteristics of new strawberry (*Fragaria x ananassa* Duch.) cultivars by HPLC-MS and Imaging Tristimulus Colourimetry. *Food Research International*, *76*(2015), 645-653. DOI: 10.1016/j.foodres.2015.07.038

Gasparrini, M., Forbes-Hernandez, T. Y., Giampieri, F., Afrin, S., Alvarez-Suarez, J. M., Mazzoni, L., ... Battino, M. (2017). Anti-inflammatory effect of strawberry extract against LPS-induced stress in RAW 264.7 macrophages. *Food and Chemical Toxicology*, *102*(1), 1-10. DOI: 10.1016/j.fct.2017.01.018

Giampieri, F., Alvarez-Suarez, J. M., & Battino, M. (2014). Strawberry and human health: Effects beyond antioxidant activity. *Journal of Agriculture and Food Chemistry*, *62*(18), 3867-3876.

Giampieri, F., Forbes-Hernandez, T. Y., Gasparrini, M., Alvez-Suarez, J. M., Afrin, S., Bompadre, S., ... Battino, M. (2015). Strawberry as a health promoter: An evidence based review. *Food & Function*, *6*(5), 1386-1398. DOI: 10.1039/c5fo00147a

Giampieri, F., Forbes-Hernandez, T. Y., Gasparrini, M., Afrin, S., Cianciosi, D., Reboredo-Rodriguez, P., ... Battino, M. (2017). The healthy effects of strawberry bioactive compounds on molecular pathways related to chronic diseases. *Annals of the New York Academy of Sciences*, *1398*(1), 62-71. DOI: 10.1111/nyas.13373

Giusti, M. M., & Wrolstsad, R. E. (2001). Anthocyanins: characterization and measurement with uv-visible spectroscopy. In M. M. Giusti, & R. E. Wrolstad (Eds.), *Current Protocols in Food Analytical Chemistry* (F1.2.1.-F1.2.13). Hoboken, US: John Wiley and Sons, Inc.

Guimarães, R. R., Vendramini, A. L. A., Santos, A. C., Leite, S. G. F., & Miguel, M. A. L. (2013). Development of probiotic beads similar to fish eggs. *Journal of Functional Foods*, *5*(2), 968-973. DOI: 10.1016/j.jff.2013.01.002

Hernández, J. M. V., Cardoso, G. M., Espinoza, J. A. M., Hinojosa, C. V., Sánchez, F. D. L., Cabrera, F. R., ... Flores, L. J. P. (2017). Antioxidant capacity *in vitro* and in vivo of various ecotypes of mexican plum (*Spondias purpurea* L.). *Journal of Food Science*, *82*(11), 2576-2582. DOI: 10.1111/1750-3841.13862

Hossain, A., Begum, P., Salma Zannat, M., Hafizur Rahman, M., Ahsan, M., & Islam, S. N. (2016). Nutrient composition of strawberry genotypes cultivated in a horticulture farm. *Food Chemistry*, *199*(1), 648-652. DOI: 10.1016/j.foodchem.2015.12.056

Instituo Adolfo Lutz [IAL]. (2005). *Métodos físico-químicos para análise de alimentos*. Brasília, DF: Ministério da Saúde.

Lajous, M., Rossignol, E., Fagherazzi, G., Perquier, F., Scalbert, A., Clavel-Chapelon, F., & Boutron-Rault, M. C. (2016). Flavonoid intake and incident hypertension in women. *American Journal of Clinical Nutrition*, *103*(4), 1091-1098. DOI: 10.3945/ajcn.115.109249

Li, X., Xu, J., Tang, X., Liu, Y., Yu, X., Wang, Z., & Liu, W. (2016). Anthocyanins inhibit trastuzumab-resistant breast cancer in vitro and in vivo. *Molecular Medicine Reports*, *13*(5), 4007-4013. DOI: 10.3892/mmr.2016.4990

Liu, L., Ji, M. L., Chen, M., Sun, M. Y., Fu, X. L., Li, L., ... Zhu, C. Y. (2016). The flavour and nutritional characteristic of four strawberry varieties cultured in soilless system. *Food Science and Nutrition*, *4*(6), 858-868. DOI: 10.1002/fsn3.346

Macfie, H., & Bratchell, N. (1989). Designs to balance the effect of order of presentation and first-order carry-over effects in Hall tests. *Journal of Sensory Studies*, *4*(1), 129-148.

Maksimović, J.D., Poledica, M., Mutavdžić, D., Mojović, M., Radivojević, D., & Milivojević, J. (2015). Variation in nutritional quality and chemical composition of fresh strawberry fruit: combined effect of cultivar and storage. *Plant Foods for Human Nutrition*, *70*(1), 77-84. DOI: 10.1007/s11130-014-0464-3

Meilgaard, M. C., Civille, G. V., & Carr, B. (2015). *Sensory evaluation techniques* (5th ed.). Boca Raton, US: CRC Press.

Merrill, A. L., & Watt, B. (1973). *Energy value of foods: basis and derivation*. Washington, DC: USDA.

Miller, N. J., & Rice-Evans, C. (1997). The relative contribution of ascorbic acid and phenolic antioxidants to the total antioxidant activity of orange and apples fruits juices and blackcurrant drinks. *Food Chemistry*, *60*(3), 331-337.

Muzzaffar, S., Jan, R., Wani, I. A., Masoodi, F. A., Munaff Bhat, M., Wani, T. A., & Wani, G. R. (2016). Effect of preservation methods and storage period on the chemical composition and sensory properties of strawberry crush. *Cogent Food & Agriculture*, *2*(1), 1-11. DOI: 10.1080/23311932.2016.1178691

Nour, V., Trandafir, I., & Cosmulescu, S. (2017). Antioxidant compounds, nutritional quality and colour of two strawberry genotypes from *Fragaria x Ananassa*. *Erwerbs-Obstbau*, *59*(2), 123-131. DOI: 10.1007/s10341-016-0307-5

Okut, D., Devseren, E., Koç, M., Ocak, Ö. Ö., Karataş, H., & Kaymak-Ertekin, F. (2018). Developing a vacuum cooking equipment prototype to produce strawberry jam and optimization of vacuum cooking conditions. *Journal of Food Science and Technology*, *55*(1), 90-100. DOI: 10.1007/s13197-017-2819-x

Oliveira, A., Gomes, M. H., Alexandre, E. M. C., Poças, F., Almeida, D. P. F., & Pintado, M. (2015). Phytochemicals preservation in strawberry as affected by pH modulation. *Food Chemistry*, *170*(1), 74-83. DOI: 10.1016/j.foodchem.2014.07.156

Paparozzi, E. T., Meyer, G. E., Schlegel, V., Blankenship, E. E., Adams, S. A., Conley, M. E., ... Read, P. E. (2018). Strawberry cultivars vary in productivity, sugars and phytonutrient content when grown in a greenhouse during the winter. *Scientia Horticulturae*, *227*(1), 1-9. DOI: 10.1016/j.scienta.2017.07.048

Pátkai, G. (2012). Fruit and Fruit Products as Ingredients (2nd ed.). In *Handbook of Fruits and Fruit Processing* (p. 263-275). Oxford, UK: Wiley-Blackwell. DOI: 10.1002/9781118352533.ch16

Peretto, G., Du, W., Avena-bustillos, R. J., Bouy, S., Sarreal, L., Sheng, S., ... Mchugh, T. H. (2014). Postharvest Biology and Technology Increasing strawberry shelf-life with carvacrol and methyl cinnamate antimicrobial vapors released from edible films. *Postharvest Biology and Technology*, *89*, 11-18. DOI: 10.1016/j.postharvbio.2013.11.003

Perla, V., Nimmakayala, P., Nadimi, M., Alaparthi, S., Hankins, G. R., Ebert, A. W., & Reddy, U. K. (2016). Vitamin C and reducing sugars in the world collection of *Capsicum baccatum* L. genotypes. *Food Chemistry*, *202*(1), 189-198. DOI: 10.1016/j.foodchem.2016.01.135

Raghuramulu, N., Madhavan, N. K., & Kalyanasundaram, S. (2003). *A manual of laboratory techniques*. Hyderabad, IN: National Institute of Nutrition, Indian Council of Medical Research.

Rendeiro, C., Rhodes, J. S., & Spencer, J. P. E. (2015). The mechanisms of action of flavonoids in the brain: Direct versus indirect effects. *Neurochemistry International*, *89*(1), 126-139. DOI: 10.1016/j.neuint.2015.08.002

Šamec, D., Maretić, M., Lugarić, I., Mešić, A., Salopek-Sondi, B., & Duralija, B. (2016). Assessment of the differences in the physical, chemical and phytochemical properties of four strawberry cultivars using principal component analysis. *Food Chemistry*, *194*(1), 828-834. DOI: 10.1016/j.foodchem.2015.08.095

Shivavedi, N., Kumar, M., Tej, G. N. V. C., & Nayak, P. K. (2017). Metformin and ascorbic acid combination therapy ameliorates type 2 diabetes mellitus and comorbid depression in rats. *Brain Research*, *1*(1674), 1-9. DOI: 10.1016/j.brainres.2017.08.019

Skrovankova, S., Sumczynski, D., Mlcek, J., Jurikova, T., & Sochor, J. (2015). Bioactive compounds and antioxidant activity in different types of berries. *International Journal of Molecular Sciences*, *16*(10), 24673-24706. DOI: 10.3390/ijms161024673

Souza, V. R., Pereira, P. A. P., Silva, T. L. T., Lima, L. C. O., Pio, R., & Queiroz, F. (2014). Determination of the bioactive compounds, antioxidant activity and chemical composition of Brazilian blackberry, red raspberry, strawberry, blueberry and sweet cherry fruits. *Food Chemistry*, *156*(1), 362-368. DOI: 10.1016/j.foodchem.2014.01.125

Tahir, H. E., Xiaobo, Z., Jiyong, S., Mahunu, G. K., Zhai, X., & Mariod, A. A. (2018). Quality and postharvest-shelf life of cold-stored strawberry fruit as affected by gum arabic (*Acacia senegal*) edible coating. *Journal of Food Biochemistry*, *42*(3), 1-10. DOI: 10.1111/jfbc.12527

Zeliou, K., Papasotiropoulos, V., Manoussopoulos, Y., & Lamari, F. N. (2018). Physical and chemical quality characteristics and antioxidant properties of strawberry cultivars (*Fragaria x ananassa* Duch.) in Greece: Assessment of their sensory impact. *Journal of the Science of Food and Agriculture*, *98*(11), 4065-4073. DOI: 10.1002/jsfa.8923