

Original Research Article

Nutrient solution for production and quality of strawberry grown in substrate

ABSTRACT

Aims: This study determined a nutritive solution and evaluated the performance in the development, production and quality of strawberry cultivated in substrate.

Study design: The treatments were the commercial and recommended nutritional solutions for the strawberry using the methods of Castelane and Araújo (C.A.), Furlani and Fernandes Junior (F.F.J.) and the proposed solution, with seven replicates.

Place and Duration of Study: The experiment was carried out in the experimental area of the Federal Technological University of Paraná, Brazil, in the period between May and December 2014.

Methodology: Agronomic variables such as yield and number of fruits, nutrient content, physiological indicators and physical chemical characteristics of fruits were analyzed.

Results: The proposed nutrient solution resulted in larger masses of fresh matter ($225.4 \text{ g plant}^{-1}$) and dry matter ($27.5 \text{ g plant}^{-1}$), number of fruits (40.1), fresh fruit mass (g plant^{-1}), in relation to the other evaluated solutions. The proposed solution resulted in better physical and chemical characteristics such as soluble solids, reducing and total sugars, anthocyanins, flavonoids, phenolic compounds and ascorbic acid and the strawberry fruits presented an attractive coloration and met the quality standards for the consumer. The highest levels of nitrogen (33.7 g kg^{-1}), phosphorus (9.3 g kg^{-1}), and potassium (28.2 g kg^{-1}) in the leaf tissue were found in the proposed solution and contributed to productivity and fruit quality gains of a strawberry.

Conclusion: These results provide a nutrient base and can be adapted to other cultivars in different locations.

Keywords: *Fragaria x ananassa* Duch.; nutrients; color; physical and chemical characteristics

1. INTRODUCTION

The strawberry (*Fragaria x ananassa* Duch.) is one of the fruits most appreciated by consumers in different regions of the world, highlighting its color, aroma, flavor, and versatility in cooking and gastronomy. For this reason, strawberries are in great demand both in the natura and industrial processings [1].

Strawberry fruits with better physicochemical characteristics guarantee acceptance by the consumer market and increase yield in processing and industrialization. In this sense, the nutritional solution concentration, together with the use of processing techniques, have been important factors taken into account to improve the productivity and the physicochemical properties of the fruit [2].

Strawberry cultivation in substrate is a production technique used in several regions of Brazil and around the world, allowing to obtain high production and greater ergonomics in crop management [3]. The main problem faced by producers in this production system is with regard to the composition and management of the concentration of the nutrient solution.

In the literature, [4] reported that concentrations of nutrient solution with values of electrical conductivity (EC) between 1.4 and 1.8 dS m^{-1} and up to 2.0 dS m^{-1} [5] are proposed to obtain quality and productivity of strawberry fruits, but the great difficulty with most nutrient solutions is to adjust the amount of nutrients for the substrate cultivation.

In this sense, the need arises for studies with nutritive solutions with determination of ionic balance of nutrients and their relationship with yield and quality of strawberry fruits in substrate cultivation. In this study we determined a nutrient solution for strawberry and evaluated the agronomic characteristics and fruit quality. The results provide nutrient content information extracted by the plants with the proposed solution, production data and physiological indicators of fruit quality, which contribute to meet the demands of the consumer market and make the production system more sustainable.

2. MATERIAL AND METHODS

2.1 Plant Material and Growing Conditions.

The experiment was carried out in the experimental area of the Federal Technological University of Paraná, Brazil (25°42'52 "S, 53°03'94" W, 530 m altitude), in the period between May and December 2014, covered with a 150-micron plastic film.

The seedlings of the cultivar Camino Real were purchased from a suitable nurseryman of varietal quality, from Maxxi Mudas®, from Patagonia, Argentina. These were transplanted in plastic pots with a capacity of 8 L in dimensions 24 × 23 cm, placed in lines, on the soil of the protected environment, filled with sand of medium granulometry, being transplanted one plant per pot, distributed with a density of eight plants per square meter.

The replenishment of nutrients was carried out daily by means of a drip irrigation system, with drippers of the brand netafim®, with a spacing of 0.20 m and a flow of 3.2 L hour⁻¹, with a dripper per vessel, thus maintaining the sand in the field capacity. The total fertigated volume was 535.7 mm and the total irrigation time was 47.5 hours for all treatments.

The meteorological data (temperature, relative air humidity, and solar radiation) were obtained every 15 minutes using Akso® brand AK 172 dataloggers installed in meteorological shelters, located in the center of the protected environment.

The fertilizers used to compose the evaluated nutrient solutions were potassium nitrate (KNO₃), calcium nitrate Ca (NO₃)₂, monoammonium phosphate (NH₄H₂PO₄), magnesium sulfate (MgSO₄). For micronutrients the amount of 25 g per 1000 L of water of the commercial product Conmicros Standard® was used in all the nutrient solutions, which presented the concentrations of B (2.0%), CuEDTA (2.0%), FeEDTA (7.9%), MnEDTA (2.0%), Mo (0.4%), and ZnEDTA (0.8%).

The nutrient solutions after the addition of the nutrients presented the following values of electrical conductivity and pH: 2.0 and 6.0 mS cm⁻¹ for the commercial solution [6], 1.7 and 6.2 mS cm⁻¹ for the commercial solution [7], and 1.8 and 5.8 mS cm⁻¹ for the proposed solution.

In relation to the management of nutrient solutions, the fertigations were done daily, and at each application of the fertirrigation, a new solution for each treatment was prepared. Also, twice-a-week irrigations were carried out only with water to avoid salinization of the substrate. Electrical conductivity and pH were measured with conductivity and portable HI 98130 Hanna® brand portable pH meters each time the solution was prepared. pH values between 5 and 6 and electrical conductivity greater than 1.5 mS cm⁻¹ were maintained during the experiment [8].

2.2. Treatments and Experimental Design

The treatments were the commercial and recommended nutritional solutions for the strawberry using the methods [7] (C.A.), [6] (F.F.J.) and the proposed solution, with seven replicates. The amounts of nutrients used for each solution are shown in Table 1. The calculation of the proposed solution was based on ionic nutrient balance [9].

88 **Table 1. Quantities of nutrients used in the preparation of nutrient solutions for strawberry**
89 **cultivation on substrate.**

Nutrients (mg.L ⁻¹)	Commercial solution C. A.	Commercial solution F. F. J.	Proposed solution
N-NO ₃ ⁻	124.6	116.2	166.9
N-NH ₄ ⁺	5.6	5.6	31.92
P - H ₂ PO ₄ ⁻	46.5	49.6	78.12
K ⁺	195.0	234.0	182.12
Ca ⁺⁺	124.0	104.0	68
Mg ⁺⁺	24.60	36.0	13.7
S-SO ₄ ⁻	43.20	48.0	16.6

90

91

92 **2.3. Evaluated Parameters**

93

94 The content of macronutrients and micronutrients in leaf tissue was determined, and four leaves per
95 plant were completely expanded in the flowering period [10].

96 During the full flowering period (120 days after transplanting [DAT]) and at 190 DAT, measurements
97 of the relative index of total chlorophyll in the abaxial and adaxial parts of the last two expanded
98 leaves of each plant were performed at 11:00 AM using the chlorophyllometer model Clorofilog
99 Falker® brand. The fresh matter mass of fruits and number of fruits per plant was determined by
100 adding all the harvests during the evaluated period (fifteen harvests).

101 The average mass of the fruits was obtained by dividing the fresh matter mass of the fruits by the
102 number of fruits per plant. The fruits were harvested when they presented more than 75% of the
103 epidermis with pink coloration [11].

104 The fruit color was determined in 10 fruits randomly selected from each nutrient solution, using a
105 digital colorimeter (Minolta model, Cr 200 b), where the values of luminosity ("L") were determined,
106 ranging from light to dark. The value 100 corresponds to white color and the value 0 (zero), the black
107 color, and the component, which expresses the chroma degree of the fruits where, by the
108 proposed classification, the more colorful fruits present smaller values and the less colorful fruits
109 present higher values [12].

110 Soluble solids content (SS) was obtained by direct reading in Hanna® bench refractometer model HI
111 9681 using homogenized pulp and filtered at room temperature, obtaining the values in degrees
112 Brix (Brix). The determination of the acidity (T.A.) was by titration with 0.1N NaOH until it reaches pH
113 8.1. The ratio (SS/TA) was determined by dividing the soluble solids content by the titratable acidity.

114 Total sugar concentrations were determined by the method described by [13] those of reducing
115 sugars were obtained by the method [14].

116 The quantification of total phenolic compounds (mg gallic acid 100g pulp⁻¹) was carried out according
117 to spectrophotometric method of Follin-Ciocauteau, proposed by [15]. The ascorbic acid content
118 (vitamin C) was determined by standard titration method of AOAC modified by [16]. Vitamin C content

was calculated based on titration values of standard solution of ascorbic acid and the results expressed in mg of 10 g of ascorbic acid 100 g pulp⁻¹.

In the quantification of anthocyanins and flavonoids, the procedure described by [17] was used. All the physicochemical analyses were determined in a single crop, at 150 DAT, which corresponded to the peak of production. A composite sample of 100 fruits per treatment was used for all the analyses, taking seven subsamples of approximately 50 g each.

At 190 DAT, which corresponded to the end of the experiment, the mass of the fresh matter in a precision scale (0.001 g) of all the plants of the experiment was determined. After the plants were placed to dry in a forced circulation air oven at 65°C until reaching constant mass to determine the mass of the dry matter.

2.4. Statistical Analysis

The data of the experiment were submitted for analysis of variance (Test F), when the F test was significant the means were compared by Tukey's test ($P=0.05$), using "SAS Studio" [18].

3. RESULTS AND DISCUSSION

During the conduction of the experiment the average temperature was 19.2°C, the average relative humidity was 75%, and the average daily radiation was 949.7 kJ m⁻². The temperature conditions during the experiment were found to be within the ranges suitable for the crop. Temperatures that range between 18°C and 24°C are considered adequate for the development of the crop [19].

The electrical conductivity (EC) in the solutions tested ranged from 1.5 to 2.1 dS m⁻¹, with an average of 1.8 dS m⁻¹. The mean conductivity is at the upper limit of the recommended range of 1.4 to 1.8 dS m⁻¹ [6]. The pH variations of the solutions were between 5.0 and 7.0, with an average of 6.2. pH ranges between 5.5 and 6.5 are the most indicated for the culture [6].

It was observed that the EC in the evaluated solutions improved fruit quality by increasing the solids content and sugars. It was found that the evaluated solutions were within the recommended pH range for strawberry.

Nutrient solutions significantly influenced nutrient content in leaf tissue. The highest levels of nitrogen (33.7 g kg⁻¹), phosphorus (9.3 g kg⁻¹) and potassium (28.2 g kg⁻¹) in the leaf tissue were found in the proposed solution (Table 2). The other macronutrients did not differ significantly. For micronutrients, there were significant differences for the boron content in F.F.J. solution and higher iron and manganese contents in the proposed solution.

Table 2. Nutrient content in leaf tissue of fertigated strawberry with different nutrient solutions.

Nutrients	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹
Sol. C.A.	31.1 b*	7.8 b	21.8 b	11.1 ^{ns}	6.9 ^{ns}	1.1 ^{ns}	100.5 b	5.3 ^{ns}	82.6 b	194.0 b	30.0 ^{ns}
Sol.F.F.J.	30.4 b	8.0 b	23.4 b	10.9	6.8	1.2	103.0 a	5.7	81.7 b	216.5 b	29.5
P. solution	33.7 a	9.3 a	28.2 a	10.5	7.0	1.2	98.4 b	5.5	86.5 a	222.0 a	31.6
Mean	31.7	8.4	24.5	10.8	6.9	1.2	100.6	5.5	83.6	210.8	30.4
C.V. (%)	3.9	9.2	3.3	3.1	5.6	4.3	1.2	2.3	3.5	2.6	2.2

*Means followed by the same letter in the column do not differ significantly by Tukey test, at $P=0.05$;

ns: not significant; C.V.: Coefficient of variance

The macronutrients, in descending order, nitrogen (N), potassium (K), calcium (Ca), phosphorus (P), magnesium (Mg), and sulfur (S) were the nutrients extracted in greater quantity by the strawberry. The following ranges are the recommended: N, 15-25g kg⁻¹; P, 2-4 g kg⁻¹; K, 20-40 g kg⁻¹; Ca, 10-20 g kg⁻¹; Mg, 6-10 g kg⁻¹; and S, 1-5 g kg⁻¹. For boron (B), iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) are 35-100, 50-300, 30-300, 5-20, and 20-50 mg kg⁻¹, respectively [20]. The contents found in the foliar tissue for the studied solutions are superior to those suitable for N and P, within the recommended range for K, Ca, Mg, B, Fe, Mn, Zn, and Cu. No visual symptoms of nutritional deficiency were observed in the strawberry plants during the experiment.

The proposed solution resulted in the highest relative indices of total chlorophyll in the flowering phase and at the end of the crop cycle (Table 3). There was also a decrease in the relative index of total chlorophyll in the final phase of the cycle in all evaluated solutions.

The mass of the fresh and dry matter presented significant differences, being the largest accumulation of fresh (225.4 g plant⁻¹) and dry (27.5 g plant⁻¹) mass obtained in the proposed solution (Table 3). The fresh mass of the proposed solution was 6.74% higher than the Castelane and Araújo commercial solution.

Table 3. Relative index (I.R) of total chlorophyll phases full flowering and the end, masses of fresh and dry matter of shoot (MMF, MMS) of fertigated strawberry plants with different nutrient solutions.

Solutions	Full Flowering I. R. of total chlorophyll	End of cycle I. R. of total chlorophyll	M.F. (g planta ⁻¹)	M.S. (g planta ⁻¹)
C. solution C. A.	54.4 b*	50.2 b	210.2 b	21.0 b
C. solution F. F.J.	57.1 b	52.9 b	208.7 b	20.7 b
Proposed solution	62.2 a	59.4 a	225.4 a	27.5 a
Mean	57.9	54.17	215.0	23.1
C.V. (%)	9.3	8.4	20.4	22.0

*Means followed by the same letter in the column do not differ significantly by Tukey test, at $P=0.05$; C.V.: Coefficient of variance

The highest relative chlorophyll index in the proposed solution is justified by the higher nitrogen content present in the leaf tissue. The content of chlorophyll in the leaf is used to predict the nutritional level of nitrogen (N) in plants, due to the fact that the amount of this pigment correlates positively with N content in the plant [21]. This relationship is attributed mainly to the fact that 50% to 70% of the total N of the leaves is integral with enzymes, which are associated with chloroplasts [22].

The decrease of the relative index of chlorophyll in the final phase of the crop cycle can be explained by the advancing age of the leaf, because in this phase, there is a decline of photosynthetic capacity. The photosynthetic efficiency is linked to the amount of chlorophyll and, consequently, to the growth phase of the plant [23].

The results of mass of the fresh and dry matter obtained with the proposed solution may be related to the higher nutrient intake, especially the nitrogen present in the foliar tissue of the proposed solution (Table 2). Plant development, productivity, and strawberry fruit quality are strongly influenced by nitrogen fertilization [24].

Moreover, the increase of K in the plant causes an increase in the production of photoassimilates and consequently, a greater mobilization of leaf N in the synthesis of macromolecules, which in turn are used in vegetative growth and fruit production [25].

The number of fruits per plant, the average fruit mass, and the fresh fruit mass were influenced by the evaluated treatments, obtaining the best results in the proposed solution (Table 4). There were gains of 6.1% and 7.94% in the fresh fruit mass in relation to the commercial solutions F.F.J. and C.A, which can be attributed to the ionic balance of the proposed solution, which met the nutritional demand of the strawberry with nutrient amounts without excesses or deficiencies, contributing to fruit quality and sustainable management of fertilizers in agriculture.

For the luminosity (L) of the epidermis, the nutrient solutions evaluated did not present significant influence (Table 4). The values of luminosity of the evaluated solutions were below the value 29.24 and according to [12] indicate dark color. The dark color of the strawberry fruits in the evaluated solutions is a desirable characteristic for both industry and consumers, because dark red fruits are more attractive to the eyes of consumers.

For the color component or chroma value of the epidermis, the proposed solution presented darker and more colorful fruits. The "c" component expresses the color of the fruits, where values less than 24.92 indicate more coloration of the epidermis, values between 24.92 and 36.08 have intermediate color, and values above 36.08 have less colored fruits [12]. It is of great importance that the external aspect of the fruit in the commercialization is mainly in natura, the proposed solution resulted in fruits being more attractive for commercialization.

Table 4. Number of fruits plant⁻¹ (N.F.P.), mean fruit mass (M.F.M), fresh fruit mass (F.F.M.), luminosity of the epidermis, coloring of the epidermis (Chroma) of fertigated strawberry with nutritive solutions.

Solution	N.F.P. (fruits plant ⁻¹)	M.F.M. (g)	FFM (g planta ⁻¹)	Luminosity	Chroma
C. solution C.A.	30.3 b*	12.5 b	690.8 b	28.7 ^{ns}	35.1 a
C. solution F.F.J.	32.5 b	13.3 b	704.6 b	27.8	34.93 a
Proposed solution	40.1 a	15.7 a	750.4 a	26.0	32.10 b
Mean	34.3	13.83	715.3	27.8	34.0
C.V. (%)	22.4	13.7	27.8	3.81	3.87

*Means followed by the same letter in the column do not differ significantly by Tukey test, at $P=0.05$.

^{ns} not significant, by the Tukey test, at $P=0.05$;

C.V.: Coefficient of variance

The superiority in the number of fruits and fresh fruit mass in the proposed solution can be attributed to the ionic balance of the solution, which favored the absorption of some ions, such as potassium (28.2 g kg⁻¹) (Table 2), which improved productivity and fruit quality (Andriolo et al. 2010). The increase in the mean mass of fruits, influenced by the potassium present in the proposed solution, can be attributed to the important role that this nutrient plays in the translocation of photoassimilates from the leaves to the fruits and the role it exerts in cell extension [25].

The number of fruits found in the proposed solution was 33.9% higher than that observed by [27], where 26.5 fruits per plant with the cultivar Camino Real in cultivation were carried out in the soil. The

239 fresh fruit mass transformed into yield results in 60 t ha⁻¹, which is higher than the yield obtained from
240 9.07 and 10.55 t ha⁻¹, with the same cultivar in conventional and organic systems, respectively [28].

241
242 The proposed solution resulted in more colored fruits, with a higher content of soluble solids and of
243 total and reducing sugars, possibly due to the higher content of potassium. Potassium is one of the
244 nutrients most used by strawberry, considered the “element of quality” in plant nutrition, to improve
245 physical-chemical characteristics and to increase production [10].

246
247 The titratable acidity and ratio (SS/TA) were not influenced by the evaluated nutrient solutions, the
248 average value being 0.90 g.100 g pulp⁻¹ and 9.33, respectively (Table 5). It was verified that the
249 proposed nutrient solution resulted in a higher content of soluble solids and concentration of total and
250 reducing sugars, anthocyanins, flavonoids, phenolic compounds and ascorbic acid (Table 5).

251 **Table 5. Soluble solids (SS), total sugars, reducing sugars, anthocyanins, flavonoids, phenolic**
252 **compounds and ascorbic acid of fertigated strawberry fruits with different nutrient solutions.**

Solutions	S.S. °Brix	T. Sug. mg.100 mg tissue ⁻¹	R. Sug. mg.100 mg tissue ⁻¹	Anthoc. mg.100 mg tissue ⁻¹	Flav. mg.100 mg tissue ⁻¹	Phen. com. mg of Galic acid 100 g ⁻¹	Asc. acid mg 100 g ⁻¹
C. solution C. A.	8.0 b*	8.7 b	1.1 b	34.0 b	3.3 b	75.1 b	45.1 b
C. solution F. F. J.	8.2 b	9.0 b	1.3 b	35.0 b	3.1 b	76.4 b	47.0 b
Proposed solution	8.9 a	10.1 a	1.9 a	40.4 a	4.0 a	80.6 a	52.5 a
Mean	8.4	9.3	1.4	36.1	3.5	77.4	48.2
C.V. (%)	8.1	7.7	19.3	20.2	17.9	10.3	12.7

253 *Means followed by the same letter in the column do not differ significantly by Tukey test, at P=0.05.

254 C.V.: Coefficient of variance

255
256 The soluble solids content in the proposed solution was 25.3% higher than the results obtained by
257 [26] of 6.65 °Brix. The minimum values of soluble solids should be higher than 7.0 °Brix, guaranteeing
258 acceptable taste [11], all nutritional solutions presented values above 7.0 °Brix, considered
259 acceptable for consumers.

260 In the relationship between sugar content and acidity (SS/TA) there was no statistically significant
261 difference between the evaluated solutions, with a mean value of 9.33. This value meets the minimum
262 relationship patterns for strawberry fruits of 8.75 [11]. The strawberry fruits of the cultivar Camino Real
263 presented an adequate SS/TA ratio, with degree of maturation and fruit quality. The SS/TA ratio is an
264 important parameter to determine fruit maturation, as well as fruit taste evaluation, as well as an
265 indicator of fruit palatability, being directly linked to the preference and acceptance of the fruits by the
266 consumer [29].

267 Commonly, the color of the fruits can be influenced by the anthocyanins, which contributes greatly
268 to the quality evaluation, since the consumers correlate between the color and the total quality of
269 specific products [30]. The anthocyanin content in the proposed solution was higher than that reported
270 in the literature (20.93 mg 100 g⁻¹) by [31] with the same cultivar, on different commercial substrates.
271 According to [32] the anthocyanin levels may present variations related to climatic factors,
272 seasonality, degree of maturation, nutrition and type of cultivar.

273 The results of the present study indicate that the fruits of the proposed solution presented an
274 attractive coloration and fruits with higher concentrations of anthocyanins, allowing greater benefits to
275 the consumer due to the antioxidant effect.

276 As the anthocyanins content may be a criterion of choice at the time of feeding, due to the health
 277 benefits [31], the consumer will be eating higher anthocyanin content when consuming strawberries of
 278 the Camino real proposed solution. For humans, the intake of foods rich in anthocyanins, such as red
 279 fruits, is related to health benefits, as these components have high antioxidant and antitumor activity,
 280 as well as acting as an anti-inflammatory and preventing the formation of edemas [33].
 281 The phenolic compounds and ascorbic acid contents presented significant differences for the
 282 evaluated solutions. The proposed solution resulted in an increase in phenolic compounds and
 283 ascorbic acid. In the literature it is reported that potassium fertilization exerts a beneficial effect on
 284 vitamin C levels [34].

285 Furthermore, the phenolic contents found in this study are lower than those verified by [35] with the
 286 same cultivar (174.3 mg 100 g⁻¹ pulp). Phenolic compounds are significantly influenced by the genetic
 287 factors of the cultivar [36]. In addition, the "open" culture system provides a higher content of phenolic
 288 compounds than the protected environment system [37].

289 Another factor that possibly influenced the content of phenolic compounds was the temperature. It is
 290 known that the synthesis of phenolic substances is favored by the milder temperatures, especially the
 291 nocturnal ones and also the temperature variation from day to night, affects pigment deposition [38].
 292 The average temperature of 19.2 °C favored the deposition of phenolic compounds, anthocyanins and
 293 flavonoids in fruits.

294 Potassium exerts influence on phenolic content, as it is related to photosynthesis and to biosynthesis
 295 of starch and proteins. With the increase of K doses in the plant, the production of photosynthates
 296 increases, which may increase the targeting of excess carbon fixed to the pathway of shikimic acid,
 297 which is the pathway for the formation of phenolic compounds, which may increase the concentration
 298 of phenolics in the plant [39].

299 The ascorbic acid (vitamin C) in strawberry may vary according to the cultivar, stage of ripening and
 300 fertilization. It is one of the most important nutritional components in fruits and human food and its
 301 content can be used as an index of food quality [11]. In addition to mineral nutrition, the intensity of
 302 solar radiation (949.7 kJ m⁻²) associated with the time of year (summer) contributed to the increase in
 303 ascorbic acid content. The intensity and duration of fruit exposure to sunrays during growth influence
 304 the amount of ascorbic acid formed is synthesized from sugars supplied by photosynthesis, which
 305 increases with the highest incidence of radiation [38].
 306

307 The phenolic compounds and ascorbic acid contents presented significant differences for the
 308 evaluated solutions. The proposed solution resulted in an increase in phenolic compounds and
 309 ascorbic acid. In the literature it is reported that potassium fertilization exerts a beneficial effect on
 310 vitamin C levels [34].

311 Furthermore, the phenolic contents found in this study are lower than those verified by [35] with the
 312 same cultivar (174.3 mg 100 g⁻¹ pulp). Phenolic compounds are significantly influenced by the genetic
 313 factors of the cultivar [36]. In addition, the "open" culture system provides a higher content of phenolic
 314 compounds than the protected environment system [37].

315 Another factor that possibly influenced the content of phenolic compounds was the temperature. It is
 316 known that the synthesis of phenolic substances is favored by the milder temperatures, especially the
 317 nocturnal ones and also the temperature variation from day to night, affects pigment deposition [38].
 318 The average temperature of 19.2 °C favored the deposition of phenolic compounds, anthocyanins and
 319 flavonoids in fruits.

320 Potassium exerts influence on phenolic content, as it is related to photosynthesis and to biosynthesis
 321 of starch and proteins. With the increase of K doses in the plant, the production of photosynthates
 322 increases, which may increase the targeting of excess carbon fixed to the pathway of shikimic acid,
 323 which is the pathway for the formation of phenolic compounds, which may increase the concentration
 324 of phenolics in the plant [39].

325 The ascorbic acid (vitamin C) in strawberry may vary according to the cultivar, stage of ripening and
 326 fertilization. It is one of the most important nutritional components in fruits and human food and its
 327 content can be used as an index of food quality [11]. In addition to mineral nutrition, the intensity of

solar radiation (949.7 kJ m⁻²) associated with the time of year (summer) contributed to the increase in ascorbic acid content. The intensity and duration of fruit exposure to sunrays during growth influence the amount of ascorbic acid formed is synthesized from sugars supplied by photosynthesis, which increases with the highest incidence of radiation [38].

4. CONCLUSION

In this study, the proposed nutrient solution contributed to productivity gains, fruit quality and comes as an option of adequate nutrient content for the strawberry, with ionic balance, without excess nutrients. These results provide a nutrient base and can be adapted to other cultivars in different locations.

REFERENCES

1. Antunes LEC, Peres NA. Strawberry Production in Brazil and South America. International Journal of Fruit Science. 2013;13:156-161. English.
2. Almeida MEM, Martin ZJ, Makiyama PAA. Strawberry Industrialization. Agricultural Report. 1999;20:84-88. English.
3. Moraes CAG, Furlani PR. Cultivation of fruit vegetables in hydroponics in a protected environment. Agricultural Report. 1999; 20:105-113. English.
4. Paranjpe AV, Cantliffe DJ, Lamb EM, Stoffela PJ. Winter strawberry production in greenhouses using soilless substrates: an alternative to methyl bromide soil fumigation. Proceedings of the Florida State for Horticultural Science. 2003;116: 98-105.
5. Sarooshi RA, Cresswell GC. Effects of hydroponic solution composition on electrical conductivity and plant spacing on yield and quality of strawberries. Aust J Exp Agric 1994; 34: 529-535.
6. Furlani PR, Fernandes JF. Hydroponic strawberry cultivation in protected environment. In: National Strawberry Symposium. Pelotas: Embrapa Clima Temperado. 2004; p.102-115. English.
7. Castellane PD, Araujo JAC. Cultivation without soil: hydroponics. Jaboticabal: FUNEP; 1994. English.
8. Gonçalves MA, Cocco C, Picoletto L, Vignolo GK, Antunes LEC. Short-Day Strawberry Cultivars. Technical Bulletin. 2015; 322: 1-8.
9. Andriolo JL. Physiology of protected cultures. Santa Maria: Publisher UFSM; 1999. English.
10. Malavolta E, Vitti GC, Oliveira SA. Evaluation of the nutritional status of plants: principles and applications. 2nd ed. Piracicaba: Brazilian Association for Research on Potassium and Phosphate; 1997. English.
11. Chitarra MIF, Chitarra AB. Post harvest of fruits and vegetables: physiology and handling. Lavras: UFLA; 2005. English.
12. Conti JH, Minami K, Tavares FCA. Production and quality of strawberry fruits in trials conducted in Atibaia and Piracicaba. Hortic Bras. 2002; 20:10-17.
13. Dubois M, Gilles KA, Hamilton J.K, Rebers PA, Smith F. 1956. Colorimetric method for determination of sugar and related substances. Analytical Biochemistry. 1956; 28: 350-356.
14. Miller GL. 1959. Use of dinitrosalicylic and reagent for determination of reducing sugar. Analytical Chemistry. 1959; 31: 426-428.

- 374 15. Woisky RG, Salatino A. Plant analysis: some parameters and procedures for chemical
375 quality control. *J. Apic. Res.* 1998; 37: 99-105.
- 376 16. Benassi MT, Antunes AJ. A comparison of metaphosphoric and oxalic acids as solutions of
377 extracts for the determination of vitamin C in vegetables. *Archives of Biology and Technology.*
378 1998; 31: 507-513.
- 379 17. Mazaro SM, Fogola , Wagner A, Citadin I, Santos I. 2013. Potential of extracts based on
380 *Calendula officinalis* L. on the induction of phytoalexin synthesis and the fungistatic effect on
381 *Botrytis cinerea*, *in vitro*. substrates. *Rev. Bras. Pl.* 2013;15: 208-213.
- 382 18. Sas Institute. Sas Studio. Accessed 15 August 2014. Available:
383 http://www.sas.com/en_us/software/university-edition.html//.
- 384 19. Ronque VER. Strawberry culture: review and practice. Curitiba: EMATER; 1998. 206p.
385 English.
- 386 20. Tedesco MJ, Gianello C, Anghinoni I, Bissani CA, Camargo FAO, Wiethölter S. Fertilization
387 and liming manual for the RS and SC states. Porto Alegre: Brazilian Society of Soil Science;
388 2004. English.
- 389 21. Smeal D, Zhang H. Chlorophyll meter evaluation for nitrogen management in corn. *Commun*
390 *Soil Sci Plant Anal.* 1994; 25: 1495-1503.
- 391 22. Stoking CR, Ongun A. The intracellular distribution of some metallic elements in leaves. *Am.*
392 *J. Bot.* 1962; 49: 284 - 289.
- 393 23. Conceição HEO, Oliva MA, Lopes NF, Rocha OGN. Resistance to drought in rubber trees.
394 *Pesqui. Agropecu. Bras.* 1985; 20: 1041-1050.
- 395 24. Otto RF, Morakami RK, Reghin MY, Caires EF. Cultivars of strawberry  neutral day:
396 production as a function of doses of nitrogen during the summer. *Hortic. Bras.* 2009; 27: 217-
397 221. English.
- 398 25. Anttonen MJ, Hoppuls KI, Nestby MJ, Karjalainen RO. Influence of fertilization, mulch color,
399 early forcing, fruit order, planting date, shading, growing environment, and genotype on the
400 contents of selected phenolics in strawberry (*Fragaria x ananassa* Duch.) fruits. *J Agric Food*
401 *Chem.* 2006; 54: 2614-2620.
- 402 26. Andriolo JL, Jänisch DI, Schmitt OJ, Dal Picio M, Cardoso FL, Erpen L. Potassium and
403 calcium doses in plant growth, yield and quality of strawberry fruits in soilless cultivation.
404 *Cienc Rural, Santa Maria, Brazil.* 2010; 40: 267-272. English.
- 405 27. Vignolo GK, Araújo VF, Kunde RJ, Silveira CAP, Antunes LEC. Production of strawberries
406 from alternative fertilizers in pre-planting. *Cienc Rural, Santa Maria, Brazil.* 2011; 41: 1755-
407 1761. English.
- 408 28. Camargo LKP, Resende JTV, Galvão AG, Camargo CK, Baier JE. Productive performance
409 and average mass of strawberry fruits obtained from different cropping systems. *Ambience,*
410 *Guarapuava, Brazil.* 2010; 6: 281-288. English.
- 411 29. Cecatto AP, Calvete EO, Nienow AA, Costa RC, Mendonça HFC, Pazzinato AC. Culture
412 systems in the production and quality of strawberry cultivars. *Acta Scientiarum, Maringá,*
413 *Brazil.* 2013; 35: 471- 478. English.
- 414 30. Kays SJ. Preharvest factors affecting appearance. *Postharvest Biol Technol.* 1999;15: 233-
415 247.

- 416 31. Calvete EO, Nienow AA, Wesp CL, Cestonaro L, Mariani F, Fioreze I, Cecchetti D, Castilhos
417 T. Hydroponic production of strawberry in vertical column system under protected cultivation.
418 Revista Brasileira de Fruticultura, Jaboticabal, Brazil. 2007; 29: 524-529. English.
- 419 32. Clifford MN. Anthocyanins—nature, occurrence and dietary burden.
420 J Sci Food Agric. 2000; 80: 1063-1072.
- 421 33. Aaby K, Wrolstad, RE, Ekeberg D, Skrede G. Polyphenol composition and antioxidant activity
422 in strawberry purees: impact of achenes level and storage. J Agric Food Chem. 2007;
423 55:5156-5166.
- 424 34. Lee SK, Kader AA. Preharvest and postharvest factors influencing vitamin C content of
425 horticultural crops. Postharvest Biol Technol. 2000; 20: 207-220.
- 426 35. Pineli LLO, Moretti CL, Santos MS, Campos AB, Brasileiro AV, Cordova AC, Chiarello MD.
427 Antioxidants and other chemical and physical characteristics of two strawberry cultivars at
428 different ripeness stages. J Food Compost Anal. 2011; 24: 11–16.
- 429 36. Atkinson CJ, Dodds PAA, Ford YY, Le Mièrre J, Taylor JM, Blake PS, Paul N. Effects of
430 cultivar, fruit number and reflected photosynthetically active radiation on *Fragaria x ananassa*
431 productivity and fruit ellagic acid and ascorbic acid concentrations. Ann. Bot.2006; 97: 429-
432 441.
- 433 37. Hernanz D, Recamales AF, Meléndez-Martínez AJ, Gonzalez-Miret ML, Heredia FJ.
434 Assessment of the differences in the phenolic composition of five strawberry cultivars
435 (*Fragaria x ananassa* Duch.) grown in two different soilless systems. J Agric Food
436 Chem.2007; 55:1846-1852.
- 437 38. Abu-Zahra TR, Al-Ismaïl K, Shatat F. Effect of organic and conventional systems on fruit
438 quality of strawberry (*Fragaria x ananassa* Duch) grown under plastic house conditions in the
439 Jordan Valley. Acta Hortic. 2007; 741:159-171.
- 440 39. Crozier A, Jaganath IB, Clifford MN. 2006. Phenols, polyphenols and tannins: An overview.
441 In: Crozier A, Clifford MN, Ashihara H. (eds.). Plant secondary metabolites: occurrence,
442 structure and role in the human diet. Oxford: Blackwell Publishing. 2006; p.1-24.