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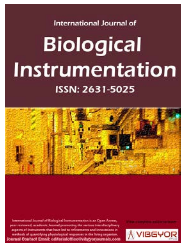

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Effect of Protected Environments on the Postharvest Quality of Strawberry (*Fragaria X Ananassa*) Produced in the Tropical Mountain Areas

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Abstract

A comparative evaluation of the postharvest quality of the strawberry fruit (*Fragaria x ananassa*) obtained from the Monterrey and Albión varieties were made, under a production system in a protected environment. Measurements of T and RH were made within the high tunnel, which were compared with data from the exterior registered in the Tibaitatá weather station. PAR radiation measurements were taken inside and outside the high tunnel. The data was recorded every hour during the crop cycle. The analysis of environmental conditions was carried out through a comparison of means using the t-student distribution, which showed significant differences between them. Measurements were made of fresh weight, surface color, percentage of acidity and total soluble solids in fruits classified in Quality 1 and Quality 2, being the fruits of Quality 1 larger than the fruits of Quality 2. The fresh weight, the color index and the maturity index were analyzed through a factorial variance analysis. In both varieties, there are fresh weight differences greater than 50% compared to the NTC 4103. The Albión variety has the highest color index and the maturity ratio shows significant differences depending on the variety and quality. It is concluded that the postharvest quality of the two varieties responds favorably to the production in high tunnel, which offers an alternative for addressing the different strawberry consumption trends in the market.

Keywords

Protected environment, Quality, High tunnel, Postharvest, Strawberry

Introduction

The climate is the most influential factor in agricultural production due to its high variability, hence the environment in which the crops are grown can be modified by means of a protected environment [1]. It is necessary to evaluate the conditions in which the plants are developed and take into account that the environmental variables affect the postharvest quality of the fruit [2-5]. Some of the environmental factors that have an important impact are temperature, relative humidity [6,7] and radiation, as it is essential as a source of energy for the synthesis of carbohydrates, a determining factor for the proper development of plants [8].

With the use of high tunnels and taking advantage of the properties of plastic films that are part of the structure, such as its insulation and light transmittance, edaphoclimatic conditions can

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be modified, such as soil, temperature, relative humidity and radiation [9-12]. The reason is that the plastic cover promotes a decrease in the intensity of the radiation and causes changes in the spectral distribution [13,14]. The changes interfere in the energy balance [13] within the high tunnel because the transmitted radiation has a direct relationship to the inside temperature [10,11,15], which in turn affects the relative humidity.

In this way, the high tunnel presents greater advantages in comparison with the production in crops with free exposure [16], since it offers the possibility of "optimizing the climatic parameters related to the growth and development of the crop" [17], and in turn provides a substantial increase in performance and quality rates [18].

When modifying the environmental conditions, it is necessary to know its effect on the postharvest quality of the fruits. The behavior of the temperature inside the high tunnel is of great importance, because it intervenes in the "metabolic activity, the absorption of water and nutrients, the gas exchange, the production and expenditure of carbohydrates and growth regulators" [13]. Additionally, an increase in temperature increases the efficiency of metabolic processes and, therefore, in crop yield [19].

Temperature is a factor that affects the chemical composition of the fruits [20], since it interferes in the formation of sugars, due to cell division and multiplication in the fruits, the alteration in the biosynthetic enzymatic activity of carbohydrates and the increase in the transpiration rate [21,22]. Likewise, it affects the color of the fruits; in the case of strawberry, the main pigment are anthocyanins, which accumulate in the vacuoles of the epidermal cells, showing tones from red to blue [23,24].

When the temperature is very low at night, there is a decrease in the content of anthocyanins that affects their antioxidant capacity [25]. The fruit coloration is measured through the color index (CI) [26], which depends on the pigmentation of the fruit surface, making it an important indicator of the quality of the strawberry. The CI values between 20 and 40 are related to tones ranging from intense to deep red [27]. Variations may occur, given the difference in the concentration of the pigments, cyanidin-3 glucoside and pelargonidin, which show magenta, crimson, pink, orange and red colors in the fruits [28].

Regarding relative humidity, the presence of high values can cause the appearance of flowering diseases that affect the formation of the fruit and later its quality [6]. Likewise, the plant responds unfavorably when the humidity of the air is high, since it restricts the gas exchanges between the stomata and the environment, limiting transpiration and, therefore, the absorption of nutrients and water [9,29,30] which affects the complete development of the plants.

Regarding radiation, it intervenes in the growth rate of the crop, which can affect the production time [31,32], the variability of the structure of the plant, the morphological development [9,11,33], the performance "as higher the amount of light intercepted by the set of levels of a plant, greater the amount of carbon assimilated" [34], the nutritional composition [35] and the quality of the fruits [10,13], due to its relationship with the photosynthetic process, the synthesis of carbohydrates [8] and secondary metabolites [33,36]. The Photosynthetically Active Radiation (PAR) captured by the plants [37] can be interpreted as the Daily Light Integral (DLI) (mol/m^2d), since it refers to the "amount of PAR received each day as a function of light intensity (instantaneous light: $\mu mol.m^{-2}.S^{-1}$)" [38].

In crops such as kiwi, tomato and avocado, the climatic conditions under which they develop affect the postharvest quality of the fruits [7,21,39]. For the kiwi, it has been established that fruits exposed to higher values of light intensity have a better quality, higher total soluble solids (TSS) content and higher fresh weight than those grown in low light [39]. Likewise, in tomato the TSS content increased when temperatures between 26 and 30 °C were reached and irradiation values between 50 and 170 J/m^2s [21]. In the case of the avocado, the maturation of the fruit is affected by its exposure to the temperature ant the degree of solar exposure of the crop during the development period, since they affect the cellular structure and, therefore, the firmness of the fruits; as well as, the content of anthocyanins and chlorophyll that determine the color of the fruit [7].

On the one hand, in the case of strawberries (strawberry, raspberry, blueberry or blackberry) [40], light intensity and temperature affect the biosynthesis of anthocyanins [8,41,42]. Likewise, radiation has an important impact on the filling and quality of the fruit [43], since the uptake of incident radiation by the plant is related to the photosynthetic capacity and, therefore, to its productive performance [44]. On the other hand, a lower amount of light hours decreases the total soluble solids content and sudden changes in temperature during day and night damage the intensity of the red color [3].

In the cultivation of raspberry (*Rubus idaeus*), it has been established that the yields are higher in the high tunnel than in the open field [22], with values up 5.5 *kg/m,* while in free exposure it is only 2.5 *kg/m* [45]. In addition, there is greater vigorousness of the plant, less presence of pests and greater weight and quality of the fruits in the protected environment [45]. Similarly, in blackberry (*Rubus Watson*) there is a higher accumulated yield, a wider harvest season and higher fruits weight [46].

In Colombia, strawberry (*Fragaria x ananassa*) is still a crop that is developed mainly in free exposure [47]. Although the crop has been adapted to different geographical areas optimally, there is a decrease in production when it is sown at high altitudes [48], between 1.200 and 2.600 m.s.n.m [49]. Therefore, its management in a protected environment favors the yield and quality of the fruits [50,51].

La Cámara de Comercio de Bogotá [49], reports that fruit formation develops adequately at temperatures that range between 18 °C and 25 °C during the day, and at night between 8 °C and 13 °C. The deformation of the fruits is due to the presence of temperatures lower than 12 °C during the fruit setting phase and when those are lower than 10 °C the fruiting process decreases significantly [52]. Otherwise, at high temperatures the flowering is reduced and the ripening of the fruits takes place in less time, causing that it does not reach the appropriate size for the harvest [51]. Regarding relative humidity, Cámara Aranda, [51] reports recommended values between 70% and 80%.

The production of the strawberry crop in high tunnel presents favorable changes regarding the time of each phenological stage; the rate of return, with a report of up to 444.59 *g/plant* the first four months of harvest; fruits with greater weight, surpassing even 40 *g* and favoring the quality of the fruits [18]. In some varieties, including Albion, the use of plastics causes changes in performance and quality, due to the manipulation of environmental conditions such as light [18]. An increase in phenolic compounds has been registered in fruits exposed to red light [53].

With the new market trends, the consumer looks for innovative products, safe and with high nutritional value [54], therefore, it is necessary to be competitive in the national and international market [55]. As described above, the objective of this work is to evaluate the response of the postharvest quality of the Monterrey and Albion varieties (*Fragaria x ananassa*), produced in a high tunnel in the Savanna of Bogotá, in order to know the potential of the product to an address the current consumers trends.

Materials and Methods

Strawberry cultivation (*Fragaria x ananassa*), Monterrey and Albión varieties, was established at the Marengo Agricultural Center-CAM (4° 40’ 55.182” N - 74° 0’ 21.388” O), located in the municipality of Mosquera, Cundinamarca. For the test, a high tunnel of 40 m long, 8 m wide and 2.50 m high in its lowest part and 2.75 m in the center was used, with a plastic cover stabilized with HALS and antioxidants. 12 elevated beds of 0.5 m wide and 38 m long were installed and 130 plants of the Monterrey and Albión varieties were placed in each one, with a substrate consisting of 50% coal slag, 25% coconut fiber and 25% rice husk. During de crop cycle, drip irrigation was used, with a sheet of 100% field capacity (FC) and application of fertilizers through fertigation.

Environmental conditions

Photosynthetically Active Radiation (PAR) ($\mu mol/m^2s$) measurements were taken, inside and outside the high tunnel with a weather station. The PAR data processed to determine the Daily Light Integral (DLI), according to the methodology described by Torres & Lopez [38]:

$$DLI\left(mol/m^2d\right) = PAR\left(\mu mol/m^2s\right)\times 0.0864$$

In addition, measurements of ambient temperature (T) and relative humidity (RH) within the high tunnel were made with a Datalogger®. The data corresponding to the open field conditions were obtained from the Tibaitatá meteorological station of the Tibaitatá Research Center (4° 41’ 44.189” - 74° 12’ 13.384”), located in the municipality of Mosquera.

The data was recorded every hour during the development period.

Postharvest variables

In the Postharvest Laboratory of fruits and vegetables of the Universidad Nacional de Colombia-Bogotá Campus, the fruits collected were classified according to size as follow:

- Quality 1: Fruits whose length is greater than 5 cm.
- Quality 2: Fruits whose length ranges between 3.5 cm and 5 cm.

For each sample, 6 fruits of each group were used. Then, the measured variables are described:

Dimensions

The determination of the maximum length and diameter of the fruits was made with a conventional calibrator, following the methodology described in de Colombian Technical Norm NTC 4103 [56].

Fresh weight

The fresh weight of the selected fruits was determined with a precision balance Precisa XT220A Model (0.0001 g).

Surface color

A Konica Minolta® CR-400 colorimeter was used for color measurement. Three measurements were taken around the equatorial zone of the fruit. The CIELab color space was used for reading the coordinates *L*, *a*, *b*. With the data obtained, the color index was determined, according to the methodology described by (Vignoni, Césari, Forte, & Mirábile [26]:

$$CI = \frac{1000a}{Lb}$$

Where:

L: Sample brightness.

a: Zone of variation between the red and green color of the spectrum.

b: Zone of variation between the yellow and blue color of the spectrum.

From the conversion of the coordinates *a, b*, the angular tone and chromaticity values were obtained, as expressed below [57]:

$$Hue^* = \tan^{-1}b^* / a^*$$

$$C^* = \sqrt{a^2 + b^2}$$

Total Titratable Acidity (TTA)

The acid neutralization procedure was applied with 0.1 N sodium hydroxide solution (*NaOH*). The result obtained is expressed as percentage of citric acid and was calculated in the following way [56]:

$$\%Acidez = \frac{V_i \times N}{V_2}$$

Where:

V_i: Volume of *NaOH* (mL).

V_2: Sample volume (5 mL).

K: Equivalent weight of citric acid (0.064 g/meq).

N: Normality of *NaOH* (0.1 meq/mL).

Total Soluble Solids (TSS)

A Kikuchi® analog refractometer was used, with a reading range between 0 and 32 °Brix for the measurement of TSS, in 5 mL of juice extracted from the selected fruits.

Maturity index

The maturity index is calculated as the quotient of the TSS and TTA values [28].

Data analysis

The statistical program Statistix version 8.0 was used. The climatic conditions were analyzed by means of two independent samples normally distributed, whose significance is based on the t-Student probability distribution, $P < 0.01$.

The postharvest variables were studied through an analysis of variance, from a factorial experiment of two factors, which correspond to the varieties; two levels for each factor, which refer to Quality 1 and 2; 6 repetitions in random blocks; and one dependent variable, which corresponds to the postharvest variable, with a significant interaction corresponding to $P < 0.05$.

Results and Discussion

Environmental conditions

There are significant differences between the values of T and RH inside and outside the high tunnel, as shown in Figure 1. On the one hand, in the high tunnel, a maximum average T of 21.69 °C and a mínimum of 12.88 °C are recorded, in comparison with the external environment where maximum and minimum average T values are 17.33 °C and 9.23 °C, respectively. On the other hand, the values of RH in the high tunnel oscillate between 85.56% and 57.60%, while they vary between 91.87% and 60.78% in the open field. Figure 1. also shows the inverse relation between T and HR.

These differences with the external conditions are the result of the implementation of plastic films that favor the formation of a microclimate [58,59] within the high tunnel. It is observed that the T in the high tunnel is higher, since the plastic coverage decreases the heat exchange with the surrounding medium [60]. In contrast, the values of T in the exterior are lower [19]. In addition, the behavior of T in the high tunnel shows a lower range of variation between maximum and minimum temperatures, hence the crop is protected against sudden changes in temperature [61], preventing plants from facing situations of thermal stress.

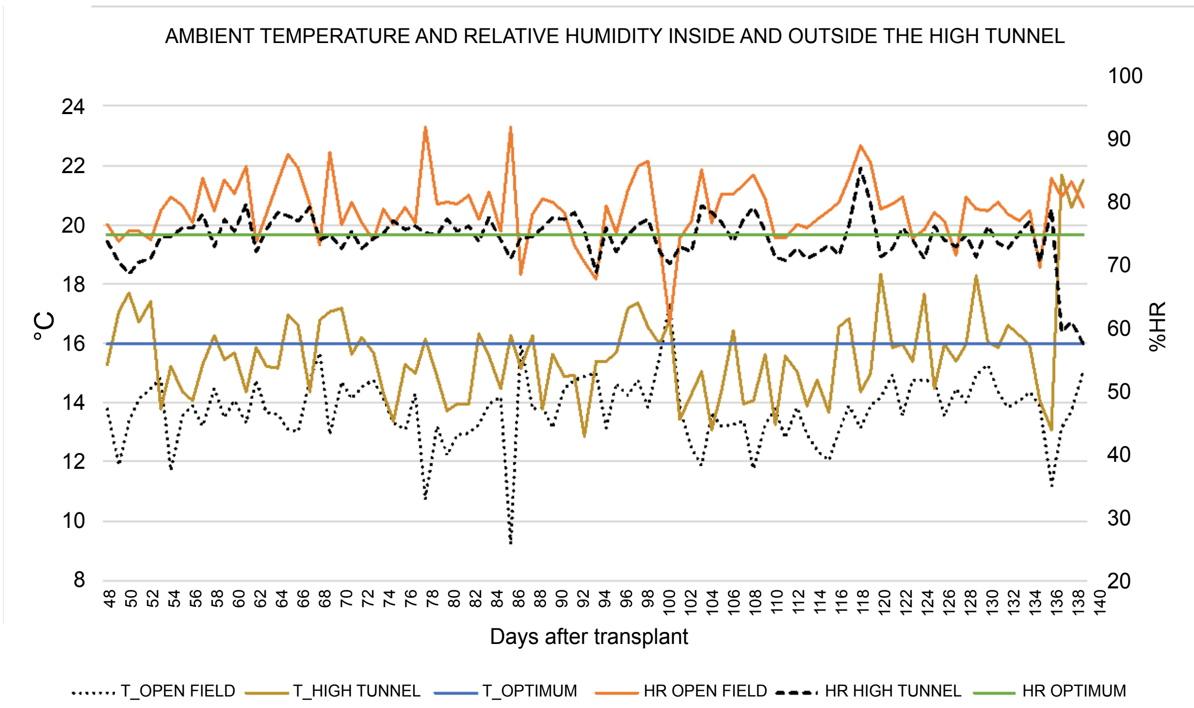

Figure 1: Behavior of ambient temperature and relative humidity inside and outside the high tunnel.

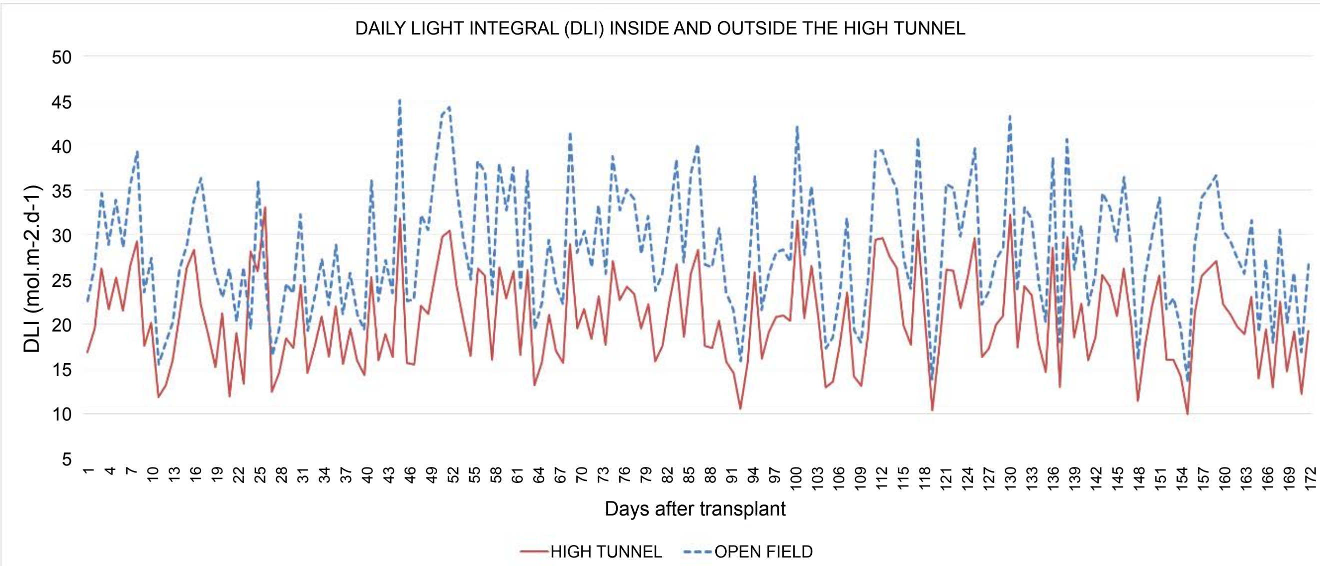

Figure 2: Behavior of the Daily Light Integral (DLI) inside and outside the high tunnel.

The range of variation between the maximum and minimum average values of T is 40.65% in the high tunnel and 46.76% in the open field. Give that there is less fluctuation of the T in the protected environmental, it is possible to coincide with Pérez de Camacaro, et al. [62], who reported that a more uniform behavior of the T and high values of RH, can increase the fresh weight and the size of the strawberry, since there is decrease in the respiration rate and therefore a greater accumulation of photoassimilates. Likewise, they expose that there is a greater accumulation of TSS, due to the reduction in the degradation of sugars.

According to the standards of the Cámara de Comercio de Bogotá [49] and Cámara Aranda [51], it can be observed that the conditions of T and HR in the high tunnel are close to the optimum values for the development of the strawberry crop, which makes it a good indicator for this production system.

Regarding radiation, it was determined that there are significant differences between the values of DLI (mol/m^2d) recorded inside and outside the high tunnel, as shown in Figure 2. It can be established that the lowest values are present in the high tunnel due to the use of plastic film. The optical characteristics of plastics can alter the transmitted light spectral composition [11,63], unlike external conditions, where the incidence of radiation is direct.

In the open field, the DLI values oscillate between 13.57 mol/m^2d and 45.05 mol/m^2d, while in the high tunnel they are between 9.99 mol/m^2d and 33.06 mol/m^2d. This indicates an attenuation of 27% of the incident radiation thanks to the implementation of the plastic cover. The results may vary according to the geographical area where the production system is established. In the case of the Savanna of Bogotá, it is characterized by a high cloudiness [64], which causes a phenomenon of light scattering [65] and, therefore, the decrease in the PAR values registered inside the high tunnel. Likewise, the characteristics of roofing materials affect the registered PAR values, since the plastic film used has UV inhibitors, which indicates a restriction in the passage of solar radiation [66] towards the interior of the high tunnel.

The DLI values are higher outside than inside high tunnel and plants have a better development as the radiation values increase [67-69]. Consequently, it is necessary to take into consideration that having conditions where plant requirements are exceeded can negatively affect growth parameters, such as the foliar area [33]. This can occur because a greater crosslinking of the bonds between carbohydrates and ferulic acid, responsible for the expansion of epithelial cell, reduces the expansion capacity of the cell walls [33].

In addition, high radiation affects the photosynthetic system because it causes damage to the D1 protein of photosystem II, ruptures in the chloroplast membrane and a reduction in the activity of the Rubisco enzyme [70]. It also interferes with the light collecting system II, the chlorophyll synthesis and the transport of thylakoid electrons [71]. Likewise, when having a direct relationship with the temperature, situations of thermal stress and decrease of the photosynthetic rate can occur [72]. For all the aforementioned reasons, it is important to optimize the quantity and quality of light [11] within protected environments.

Postharvest variables of the Monterrey and Albión varieties

Fresh weight: It was established that there are statistically significant difference ($P < 0.05$) in the fresh weight of the fruits according to the quality of each variety, Monterrey and Albión. In Figure 3, it is observed that Quality 1 of both varieties registers values superior to those of Quality 2. In the case of the Monterrey variety, it corresponds to 53.80 g and for the Albión variety, to 48.15 g. For quality 2, fresh weight values correspond to 27.43 g and 23.77 g in Monterrey and Albión varieties, respectively.

When appreciating the diameter measurements, the average value of the fruits of Quality 1 is 4.74 cm for the Monterrey variety and 4.70 cm for the Albión variety, while for the fruits of Quality 2 it is 3.83 cm and 3.76 cm, respectively. When evaluating the dimensions of the fruits, a similar trend can be established between fresh weight and size [6,9,28]. As the fruit develops, there is a filling of it, which will cause an increase in weight [44], and in turn an increase in size [73]. This increase is largely determined by the period of development of the fruit before harvest.

Medina Bolívar, et al. [74] report that, in the case of the Albión variety, an average weight of 32 g is registered, and López Valencia, et al. [28] establish

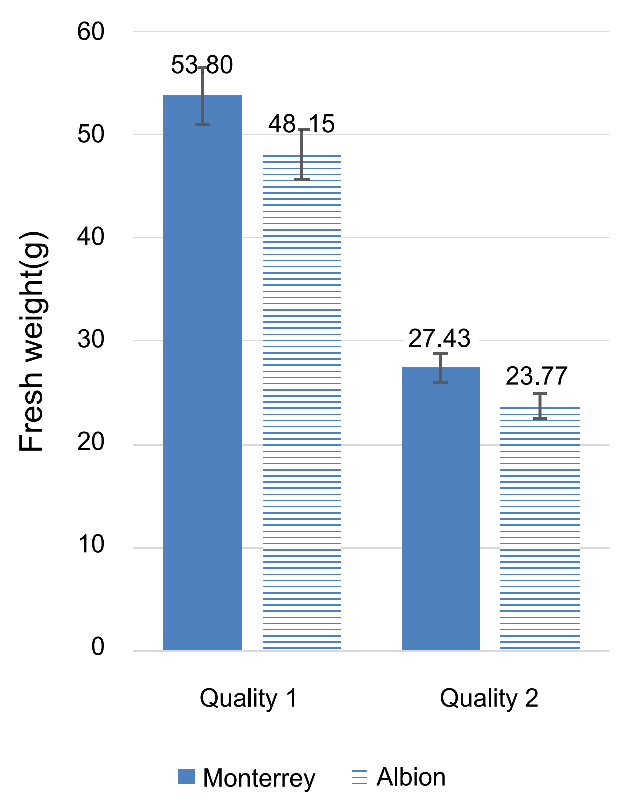

Figure 3: Fresh weight of the Monterrey and Albión varieties.

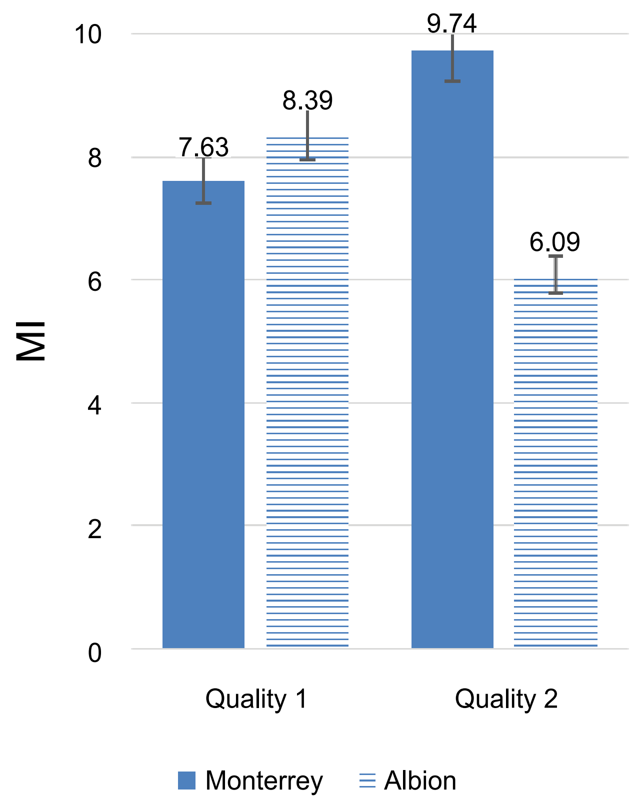

Figure 4: Maturity index (MI) of the Monterrey and Albión varieties.

that the fresh weight for the Monterrey variety can reach 25 g and 20 g for the Albión variety in an open field production system. When comparing these reports with the results obtained in the high tunnel, the fresh weight of the fruits of the Quality 1 is greater in 53.53% for the Monterrey variety and up to 58.46% for the Albión variety.

This shows that fruits of higher fresh weight are obtained in the high tunnel, since there is a favorable effect of radiation. There is an incidence of the quality and quantity of light in the enzymatic activity [75], due to its relationship with the photosynthetic capacity of the plants and the production of photoassimilates for fruit filling [6].

The fruits evaluated meet the requirements of national and international regulations. In the case of the Colombian Technical Standard NTC 4103 (Chandler variety), the average fresh weight of the fruits belonging to the Extra Category corresponds to 21.8 g, which is exceeded in 59% by the Monterrey variety and in 50% by the Albión variety, in the fruits of Quality 1. Nonetheless, the fresh weight of the fruits classified in Quality 2 also meet the specifications of the Colombian standard.

In the international context, the quality of the fruits is measured to a large extent by the dimensions. For example, the United States Standards for Strawberry Grades establishes a minimum diameter equal to ¾ inch (1.90 cm) [76]; and the Regulation (EC) N° 843/2002 of the Commission of the European Communities and the Resolution 866/2012 of the previous Ministry of Agriculture, Livestock and Fisheries of Argentina have a minimum caliber of 2.5 cm for the fruits of the Extra Category [77,78]. When comparing the diameter values of the fruits produced in the high tunnel with the requirements of the international polices, it can be determined that there are favorable differences of 47.26% with the Monterrey variety and 46.80% with the Albión variety.

Maturity Index (MI): The higher the maturity index (MI), the higher the TSS content and lower the percentage of acidity, which can change depending on the variety [35]. In Figure 4, it is observed that the maximum values of the maturity index are 9.74 for the Monterrey variety and 8.39 for the Albión variety.

The results obtained for both varieties are similar to those obtained by López Valencia, et al. [28], who recorded that the MI for the Monterrey and Albión varieties oscillates between 8 and 10, where the fruits of the Monterrey variety have the highest value of IM. If the maturity is high, the fruit has a more pleasant taste [41] for the consumer.

These varieties, are characterized by a high accumulation of TSS [28]. The analyzed fruits of the Monterrey variety register an average 7.7 °Brix, while the Albión variety reports 7.6 °Brix. The results obtained from the TSS content of the Albión variety agree with registered by Ferrucho González & Ruíz González [18], who report that same value.

López Valencia, et al. [28] report TSS content between 6.5 and 7 °Brix for the Monterrey variety and between 6 and 6.5 °Brix for the fruits of the Albión obtained in an open field production system. When comparing these values with the results obtained in the high tunnel, the TSS content of the Monterrey fruits is higher up to 15.58% and for the Albión variety to 21.05%.

These results are relevant, since the TSS content may vary among fruits, according to the variety. The Cámara de Comercio de Bogotá [49] reports that the TSS can range between 6.7 and 7.28 °Brix, and ICONTEC [56] reports between 7.9 and 8.5 °Brix (Chandler variety). In the international scenario, the previous Ministry of Agriculture, Livestock and Fisheries [78] of Argentina establishes a minimum quality protocol of 7.0 °Brix, whose value is surpassed by the fruits obtained in the high tunnel in 10% for the Monterrey variety and in 8.57% for the Albión variety.

These differences can be presented due to the characteristics of each crop. Since they have a different yield, when producing a greater amount of fruit, the plant incurs an increase in the distribution of photoassimilates, which reduces the TSS content [18,79].

On the other hand, the radiation to which the plants are exposed is a determining factor. When modifying the chemical composition of the fruits through the intervention in the photoreceptor pigments, the formation and accumulation of sugars of all kinds can occur [68,20].

Color index (IC): Statistically significant differences were found ($P < 0.05$) between varieties, because the genotypes differ in their biochemical response capacity according to the cultivation conditions [24,25,35,36,79].

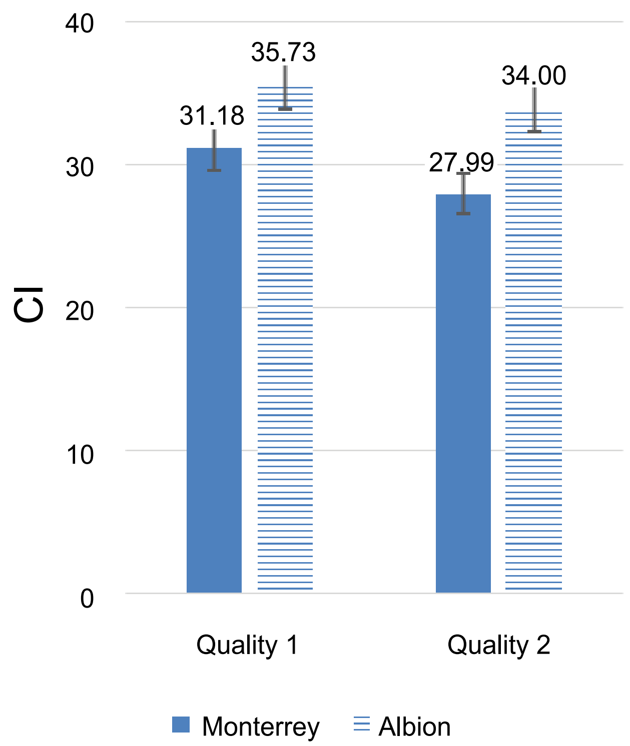

Figure 5: Color index (IC) of the Monterrey and Albión varieties.

On the other hand, when observing Figure 5, it can be established that the IC for the Monterrey variety correspond to 31.18 and 27.99, while for the Albión variety it is 35.73 and 34, which means that the Albión variety produces intense red fruits. According to Angulo Carmona [80] and Chicaiza Flores [81], this difference is due to a greater accumulation of pigments [82,83]. Although, the Monterrey variety has a less intense red, it shows the characteristic color of the fruit.

On the other hand, when analyzing the data obtained from the CIELab color space, the fruits of the Monterrey variety show higher luminosity values compared to the Albion variety. However, its epidermis shows greater variation between the yellow and blue colors of the spectrum, which has an inversely proportional relationship to the CI value and coincides with the CI value presented in Figure 5.

Although, the Albión variety has its own characteristics, it presents a more intense red color than the Monterrey variety, when contrasting the results obtained with the records of López Valencia, et al. [28], which register an IC close to 50 and 60 for the Monterrey and Albión varieties, respectively. The decrease of CI in the evaluated fruits is evident,

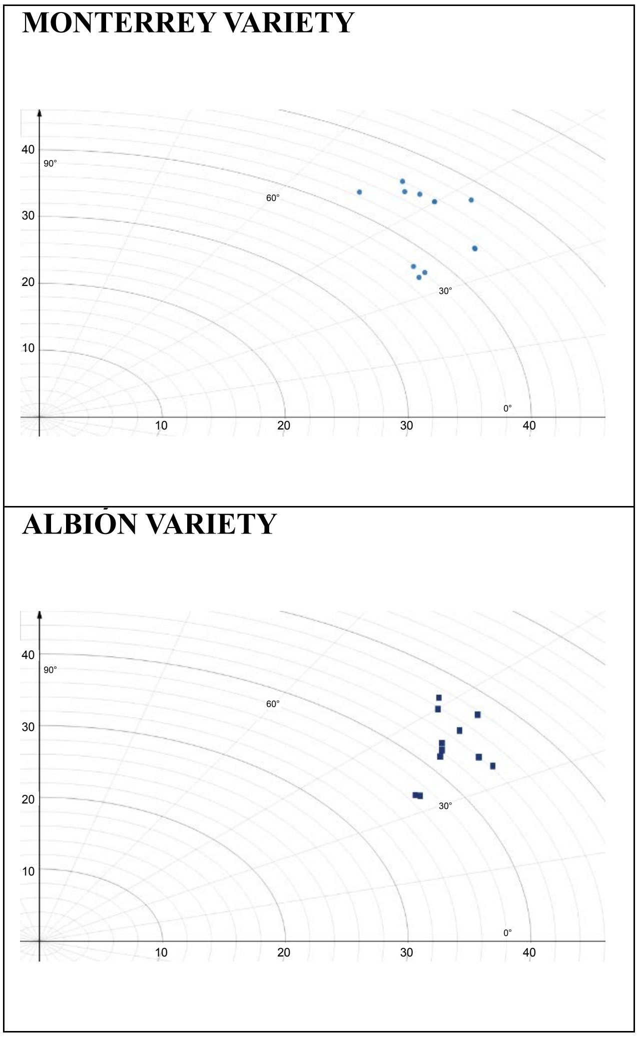

Figure 6: Color diagram of the Monterrey and Albión variety.

given that it is affected by the radiation and the temperature to which the plants are exposed.

The exposure of plants to high values of solar radiation with a preponderance of short wavelengths in the light spectrum causes a greater synthesis of anthocyanins during maturation, harvest and postharvest, since is affects the expression of genes along the flavonoid pathway and the transcriptionists involved [24,36]. Likewise, temperature is a factor that effects the stability of anthocyanin, since its increase induces the loss of glycosylating sugar in the molecule and the production of colorless chalcones [42].

Identifying the incidence of these variables in the CI allows to establish that the decrease in the radiation values and the increase of the temperature in the high tunnel cause the reduction of the IC obtained in the fruits of both strawberry varieties. However, the CI obtained is within the range that defines the colors from intense red to deep red.

Figure 6, shows the color diagram for the Monterrey and Albión variety. The points indicate the distribution of color around the fruit: the greater the dispersion, the lower the color homogeneity in the strawberry. It can be determined that the red color is distributed more evenly in the fruits of the Albión variety, which diminishes the presence of tones that can range from pale yellow to green. In the case of the fruits of the Monterrey variety, the distribution of the red color is less homogeneous.

Conclusions

Positive results were obtained from the physical and chemical variables evaluated in fruits of the Monterrey and Albion varieties produced in a high tunnel. The highest fresh weight corresponds to the fruits classified in Quality 1 of both varieties. In comparison with the fresh weight specified in the NTC 4103 for the Extra Category, the Monterrey variety was higher by 59% and the Albion variety by, 55%. However, the weights recorded for the fruits of Quality 2 can be considered acceptable, if they are compared with the requirements of the NTC 4103.

The Monterrey variety had a higher TSS content than the Albión variety and a higher MI than the one stablished by the NTC 4103. However, both varieties show IM values similar to those stated in the standard, which is related to a pleasant taste and, therefore, to a good reception by the consumer. Regarding color, the Albion variety showed favorable results, with a more homogeneous fruit color, which makes it a more desirable variety and visually more attractive in the market. However, the fruits of the Monterrey variety show a tolerable distribution of color for commercialization.

When comparing the results with the Regulation No. 843/2002 of the Commission for the European Communities, the United States Standards for the Grades of Strawberries and Resolution No. 866/2012 of the Ministry of Agriculture, Livestock and Fisheries from Argentina, it is established that the fruits have the adequate quality. They satisfy the values of minimum size, since the diameter of the evaluated fruits exceeds the requirements by 47.26% in the Monterrey variety and 46.80% in the Albión variety.

The coloring features are also favorable, as they show an adequate distribution of the characteristic color around the fruit. In addition, the content of TSS agrees with the provisions for marketing of the Resolution No. 866/2012 of the Ministry of Agriculture, Livestock and Fisheries of Argentina. These indicators show that the national product does not only meets the standards of the Colombian Technical Standard, but it is also apt to compete in the international market.

The postharvest quality of the strawberry in the high tunnel for both varieties was beneficial, since fruits of greater weight and size were obtained. In addition, a high maturity ratio, high color indices and more uniform distributions were obtained, which are striking attributes for the consumer and the industry. Currently, the market demands products with high nutritional value and attractive organoleptic characteristics. Likewise, when handling varieties with different maturity and weight ratio, different consumption trends can be attended in national and international markets.

For all the aforementioned reasons, the use of high tunnels and the properties offered by plastic covers favor production in a protected environment, which increases the competitiveness of the producer, by offering good quality products. It also opens the possibility of inclusion of other technologies for greater control of the microclimate and favoring of the needs of the crop and the improvement of its quality.

References

1. JJ Hueso Martin, F Alonso López, V Pinillos Villatoro, J Cuevas González, Fundación Cajamar, et al. (2012) Protected crop of plant species. Cuadernos de estudios agroalimentarios 139-160.
2. CA Lara Gutiérrez, JF Acuña Caita, G Quintero Arias (2015) Effect of diffusivity light levels in greenhouse production about quality storage of Mentha spicata, Saltillo, Coahuila, 8.
3. J Lado, E Vicente, A Manzzioni, B Ghelfi, G Ares (2012) Evaluation of fruit quality and acceptability of different strawberry cultivars. Agrociencia Uruguay 16: 52-58.
4. G Fischer (2010) Environmental conditions that affect growth, development and quality of the pasifloraceas. Huila 10-22.
5. F Martínez, JA Oliveira, E Oliveira Calvete, P Palencia (2017) Influence of growth medium on yield, quality indexes and SPAD values in strawberry plants. Scientia Horticulturae 217: 17-27.
6. Parra Coronado (2014) Effect of climatic conditions on the growth and post-harvest quality of the fruit of the feijoa (Acca sellowiana (O. Berg) Burret), Bogotá, Colombia.
7. SA Rivera, R Ferreyra, P Robledo, G Selles, ML Arpaia, et al. (2017) Identification of preharvest factors determining postharvest ripening behaviors in 'Hass' avocado under long term storage. Scientia Horticulturae 216: 29-37.
8. G Fischer, CP Pérez (2012) Effect of solar radiation on the quality of horticultural products.
9. RD Zaragoza Nieto (2013) Evaluation of hydroponic production techniques in strawberry cultivation (Fragaria x ananassa) under greenhouse. Saltillo: Centro de Investigación en Química Aplicada 85.
10. EL García Enciso, M De La Rosa Ibarra, R Mendoza Villareal, MR Quezada Martin, M Arellano García (2014) Effect of a modified plastic film on some biochemical aspects of a tomato (Solanum lycopersicum L.) crop. Ecosistemas y Recursos Agropecuarios 1: 151-162.
11. EL García Enciso, M De La Rosa Ibarra, Md R Quezada Martin, MA Arellano García (2015) Effect of a plastic film modified in agronomic aspects of tomato (Solanum lycopersicum L) Revista Mexicana de Ciencias Agrícolas 11: 2105-2113.
12. Pedro Velásquez V, Hugo Ruíz E, Germán Chaves J, Cristina Luna C (2014) Productivity of lettuce Lactuca sativa in high tunnel conditions on Vitric haplustands soil. Revista de Ciencias Agrícolas 31: 93-105.
13. Gonzalez Argandar (2010) Evaluación agronómica de películas para invernadero formuladas con nanopartículas de óxido de zinc. Saltillo, Cohahuila, 129.
14. E Espí (2012) Materiales de cubierta para invernaderos. Cuadernos de estudios agroalimentarios 71-88.
15. U Chávez Martínez (2009) Bioclimatic control of a greenhouse. The agroclimatic conditions of a greenhouse crop, achieved by the use of passive air conditioning, Coquimatlán, Colima: Universidad de Colima, 91.
16. Zenner de Polanía, F Peña Baracaldo (2013) Plastics in agriculture: Benefit and environmental cost: A review. Revista U.D.C.A Actualidad & Divulgación Científica 16: 139-150.
17. G Quintero Arias, JF Acuña C (2015) Effect of thermicity on lettuce growth variables (Lactuca

sativa) in protected environments of the Colombian high tropic. Saltillo, Coahuila, 89-98.

18. M Ferrucho González, D Ruíz González (2013) Evaluation and comparison of the agronomic behavior of two strawberry cultivars ('Albión and Monterrey') planted at free exposure and under macrotúnel in the Sabana de Bogotá (Colombia), Cajicá, 1-97.
19. Rendón-Aquino Y, Robledo-Torres V, Mendoza-Villarreal R, Ramírez-Godina F, Vázquez-Badillo ME (2015) Study of cucumber (Cucumis sativus L.) in three culture media and macro-tunnels with colored meshes, Coahuila.
20. SK Lee, AA Kader (2000) Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biology and Technology 20: 207-220.
21. M Beckles (2012) Factors affecting the postharvest soluble solids and sugar content of tomato (Solanum lycopersicum L.) fruit. Postharvest Biology and Technology 63: 129-140.
22. P Palonen, A Pinomaa, T Tommila (2016) The influence of high tunnel on yield and berry quality in three floricane raspberry cultivars. Scientia Horticulturae 214: 180-186.
23. S Chordi Barrufet (2013) Phenolic content and antioxidant capacity of minimally processed strawberry subjected to conservation treatments by pulses of high intensity light. LLeida: Universidad de Lleida, 45.
24. Castañeda Sánchez, JA Guerrero Beltrán (2015) Pigments in red fruits and vegetables: Anthocyanins. Temas Selectos de Ingeniería de Alimentos 9: 25-33.
25. LM Carvajal de Pabón, EH Yahia, R Cartagena, C Peláez, CA Gaviria, et al. (2012) Antioxidant capacity of two Fragaria x ananassa (Weston) Duchesne (strawberry) varieties subjected to variations in vegetal nutrition. Revista Cubana de Plantas Medicinales 17: 37-53.
26. LA Vignoni, RM Césari, M Forte, ML Mirábile (2006) Determination of color index in minced garlic. Información tecnológica 17: 63-67.
27. MC Nunes, JK Brecht, A Morais, SA Sargent (2006) Physicochemical changes during strawberry development in the field compared with those that occur in harvested fruit during storage. Journal of the Science of Food and Agriculture 86: 180-190.
28. López Valencia, M Sánchez Gómez, JF Acuña Caita, G Fischer (2018) Physicochemical properties of seven outstanding strawberry (Fragaria x ananassa Duch.) varieties cultivated in Cundinamarca (Colombia) during maturation. Corpoica Ciencia y Tecnología Agropecuaria 19: 1-18.
29. L Huertas (2008) Prevent diseases and pests. Environmental control in greenhouses: Relative humidity. Revista Horticultura 205: 52-54.
30. MA Torres Ramírez (2012) The physiology of the absorption and conduction of water and minerals through the xylem in vascular plants and the development of visual and spatial intelligence as a proposal for their learning. Bogotá: Universidad Nacional de Colombia 79.
31. P Palencia, F Martínez, JJ Medina, J López Medina (2013) Strawberry yield efficiency and its correlation with temperature and solar radiation. Horticultura Brasileira 31: 93-99.
32. G Quintero Arias (2015) Comparative analysis of the response of 3 varieties of lettuce (Lactuca sativa) type gourmet to production under protected environments in the Bogotá savanna, Bogotá. Cundinamarca: Universidad Nacional de Colombia 85.
33. L Carrasco Ríos (2009) Effect of ultraviolet-B radiation in plants. IDESIA 27: 59-76.
34. KF Mesa Juliani (2007) Effect of the interception of solar radiation and fruit load on productivity and fruit weight in Royal Gala var apple. Santiago de Chile: Universidad de Chile 32.
35. S Tyagi, S Sahay, M Imran, K Rashmi, S Shankar Mahesh (2017) Pre-harvest factors influencing the postharvest quality of fruits: A review. Current Journal of Applied Science and Technology 23: 1-12.
36. L Zoratti, L Jaakola, H Häggman, L Giongo (2015) Modification of sunlight radiation through colored photo-selective nets affects anthocyanin profile in vaccinium spp. Berries. Plos One 1-17.
37. MD Raffo, N Iglesias (2004) Effect of the interception and distribution of the photosynthetically active radiation in apple trees cv. Fuji, under four high density production systems. Revista de Investigaciones Agropecuarias 29-42.
38. P Torres, RG Lopez (2010) Daily light integral measurement in greenhouses.
39. Tombesi, E Antognozzi, A Palliotti (1993) Influence of light exposure on characteristics and storage life of kiwifruit. New Zealand Journal of Crop and Horticultural Science 21: 87-92.

40. FIRA (2016) Agrifood Panorama.

41. SY Wang, CT Chen, CY Wang (2009) The influence of light and maturity on fruit quality and flavonoid content of red raspberries. Food Chemistry 112: 676-684.

42. A Garzón (2008) Anthocyanins as natural colorants and bioactive compounds. A Review. Acta Biológica Colombiana 113: 27-36.

43. CYTED (2014) UCHUVA Physalis peruviana L.: Fruta andina para el mundo 1-231.

44. LJ Barrera V, G Cayón S, J Robles G (2009) Influence of the exposure of the leaves and the fruit epicarp on the development and quality of the 'Hartón' banana cluster (Musa AAB Simmonds). Agronomía colombiana 27: 73-79.

45. E Hanson, M Von Weihe, AC Schilder, AM Chanon, JC Scheerens (2011) High tunnel and open field production of floricane- and primocane-fruiting raspberry cultivars. Hortechnology 21: 412-418.

46. E Thompson, BC Strik, CE Finn, Y Zhao, JR Clark (2009) High tunnel versus open field: Management of primocane-fruiting blackberry using pruning and tipping to increase yield and extend the fruiting season. Hortscience 44: 1581-1587.

47. SA Rubio, AM Alfonso, CM Grijalba, MM Pérez (2014) Determination of the production costs of strawberry cultivated in an open field and with a high tunnel. Revista Colombiana de Ciencias Hortícolas 8: 67-79.

48. Espinoza González (2007) Diagnosis and dynamics of diseases in three genotypes of strawberry (fragaria spp.) in the community El Castillito, Las Sabanas Department of Madriz. Ingeniería thesis, Universidad Nacional Agraria, UNA.

49. Cámara de Comercio de Bogotá (2015) Strawberry manual. Bogotá 1-62.

50. Singh A, A Syndor, BC Deka, RK Singh, RK Patel (2012) The effect of microclimate inside low tunnels on off-season production of strawberry (Fragaria × ananassa Duch.). Scientia Horticulturae 144: 36-41.

51. VL Cámara Aranda (2017) Design and construction of a duct system for zoned climate control of a strawberry greenhouse. Chihuahua.

52. LO Rea Otuna (2012) Strawberry yield analysis (Fragaria chiloensis L. Duch) subjected to different types of substrates within a semi-hydroponic culture in the parish of Salinas, province of Imbabura. UTd Babahoyo, Carchi.

53. ET Paparozzi, GE Meyer, V Schlegel, EE Blankenship, SA Adams, et al. (2017) Strawberry cultivars vary in productivity, sugars and phytonutrient content when grown in a greenhouse during the winter. Scientia Hortuculturae 227: 1-9.

54. CCMA (2017) Blackberry and strawberry chain in Antioquia.

55. LA Calderón Medellín, DC Angulo Rivera, D Rodríguez Caicedo, CM Grijalba Rativa, MM Pérez Trujillo (2013) Evaluation of mulching materials on strawberry under greenhouse. Facultad de Ciencias Básicas.

56. ICONTEC (1997) Norma Técnica Colombiana NTC 4103. Fresh fruits. Strawberry Variety Chandler. Specifications. Bogotá: Instituto Colombiano de Normas Técnicas y Certificación 11.

57. J Aular, C Ruggiero, J Durigan (2002) Relationship between skin color and fruit and juice characteristics of passion fruit. Bioagro 14: 47-51.

58. S Corrales Carvajal (2010) Effect of three plastic films on the microclimate of the greenhouse and the agronomic behavior. Instituto Tecnológico de Costa Rica 1-105.

59. M Pirkner, J Tanny, O Shaphira, M Teitel, S Cohen, et al. (2014) The effect of screen type on crop micro-climate, reference evapotranspiration and yield of a screenhouse banana plantation. Scientia Horticulturae 180: 32-39.

60. Iriarte A, L Saravia, C Matias (2002) Acondicionamiento Térmico con Energía Solar de un Invernadero Rusticadero para la Producción de Plantas. Catamarca: Universidad Nacional de Catamarca 33.

61. N Iglesias (2014) Protections for horticultural crops adapted to Patagonia. (1st edn) Río Negro: Sección Comunicaciones de la EEA Alto Valle del INTA 15.

62. M Pérez de Camacaro, M Ojeda, A Giménez, M González, A Hernández (2017) Attributes of quality in strawberry fruit 'Capitola' harvested in different climate condition in Venezuela. Bioagro, 29: 163-174.

63. E Cárdenas Aguirre (2012) Effect of greenhouse films with special optical properties, on growth and yield of a cucumber crop (Cucumis sativus L.). Saltillo, Cohahuila: Universidad Autónoma Agraria Antonio Narro 86.

64. IDEAM (2013) Study of the climatic characterization of Bogotá and Cuenca Tunjuelo River. Bogotá.

65. B Brizuela, CA Aguirre, I Velasco (2007) Application of atmospheric correction methods of Landsat 5 data for multitemporal analysis,» de Teledetection

- Towards a better understanding of global and regional dynamics Ed. Martin 207-214.

66. Z Serrano Cermeño (2005) Construction of greenhouses. (3rd edn), M.Libros, 504.

67. J Grazia, PA Tittonell, Á Chiesa (2001) Effect of sowing season, radiation and nitrogen nutrition on the growth pattern and yield of the lettuce crop (Lactuca sativa L.). Invest Agr Prod Prot Veg 16: 355-365.

68. Casierra Posada, JE Peña Olmos, AF Vargas Martínez (2011) Physical and chemical properties of strawberries (Fragaria sp) grown under photoselective filters. Revista Facultad Nacional de Agronomía Medellín 64: 6221-6228.

69. Díaz Vázquez, Sonia Guadalupe (2012) Effect of radiation on phenological development, yield and quality in polyculture: Chili, tomato, corn, beans and amaranth under greenhouse conditions. Querétaro: Universidad Autónoma de Querétaro.

70. Pinto ME, Casati P, Hsu TP, Ku MS, Edwards GE (1999) Effects of UV-B radiation on growth, photosynthesis, UV-B-absorbing compounds and NADP-malic enzyme in bean (Phaseolus vulgaris L.) grown under different nitrogen conditions. J Photochem Photobiol B 48: 200-209.

71. FC Lidon, JC Ramalho (2011) Impact of UV-B irradiation on photosynthetic performance and chloroplast membrane components in Oryza sativa L. J Photochem Photobiol B 104: 457-466.

72. J Molino (2001) Thermal stress due to high temperature in soybeans (Glycine max (L.) Merr.): Analysis of production dynamics and fixation of pods and their effect. Universidad Nacional del Litoral, 79.

73. MG Ontivero Urquiza, H Abel Altube, L Baghin (2011) Evolution of the size and weight of "Hayward" kiwifruit (Actinidia deliciosa (A.Chev.) Liang et Fergurson) cultivar during the final stage of growth. Revista de la Facultad de Ciencias Agrarias 44: 99-108.

74. JS Medina Bolívar, EA Pinzón Sandoval, GE Cely (2016) Organic substrates effect in strawberry cv 'Albion' (Fragaria sp.) plants, under field conditions. Revista Ciencia y Agricultura 13: 19-28.

75. JA López Pinto (2008) Effect of different levels of luminosity on the phenolic composition and the gene expression of enzymes of the phenylpropanoid pathway in var. Carménère. Santiago de Chile: Universidad de Chile.

76. USDA (2006) United States Standards for Grades of Strawberries, United States Department of Agriculture, 3.

77. (2002) Regulation (EC) No 843/2002 of the commission of 21 May 2002 laying down the rules for the marketing of strawberries and amending Regulation (EEC) No 899/87, Official Journal of the European Communities. 5.

78. (2012) Ministry of Agriculture, Livestock and Fisheries, Resolution No. 866/2012, Ministry of Agriculture, Livestock and Fisheries.

79. Z Hussein, O Amos Fawole, U Linus Opara (2018) Preharvest factors influencing bruise damage of fresh fruits - A review. Scientia Horticulturae 229: 45-58.

80. R Angulo Carmona (2009) Fresa fragaria ananassa. Bogotá: Bayer Crop Science SA 48.

81. JJ Chicaiza Flores (2015) Determination of the physical-chemical and microbiological parameters of the strawberry (Fragaria vesca) variety Oso Grande as a basis for the establishment of the requirements standard, Ambato: Universidad Regional Autónoma de los Andes, 101.

82. Y Salinas Moreno, G Almaguer Vargas, G Peña Varela, R Ríos Sánchez (2009) Ellagic acid and anthocyanin profiles in fruits of raspberry (Rubus idaeus L.) in different ripening stages. Revista Chapingo Serie Horticultura 15: 97-101.

83. I Castañeda Vásquez (2010) Induction of anthocyanins and antioxidant capacity by oligogalacturonides in table grapes cv. 'Flame Seedless', Hermosillo. Sonora: Centro de Investigación en Alimentación y Desarrollo, AC, 96.

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