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QUALITY STABILITY ASSESSMENT OF A STRAWBERRY-GEL PRODUCT DURING STORAGE

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ABSTRACT

A strawberry-gel product was formulated by using osmotic treatment. The osmotic solution used to dehydrate the fruit was mixed with carrageenan and employed to formulate the gel. In order to prevent a further dehydration of the fruit during product storage, the osmotic solution was previously diluted so that its water activity is the same as the dehydrated fruit. Changes in water, soluble solids, citric acid, ascorbic acid and anthocyanin contents, water activity, surface color, mechanical properties and volatile profile during 15 days of storage (5ºC) were evaluated. The use of the osmotic solution increased the nutritive and functional properties of the product. Changes in volatile profile, mechanical properties and color of the strawberry occur mainly in the first two days of storage and are not due to the presence of the gel matrix, as they occur also in the samples not placed in gel. The flux of anthocyanins

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from the fruit to the gel produces redness, giving a more attractive aspect to the formulated product.

PRACTICAL APPLICATIONS

Fruit is still consumed below the recommended values for human health, particularly in developed countries. The development of new fruit based products with a high proportion of fruit and good nutritional and functional properties (such as the one proposed in this study) may be of interest in order to diversify the market supply. These products-must be attractive, especially among the young, easy to consume and with a reasonable shelf-life. Osmotic dehydration may be used to partially decrease fruit water activity obtaining high quality products. However, the osmotic solution is still difficult to manage in some cases. Thus, the use of this by-product on the fruit-gel formulation is of a great interest to eliminate environmental adverse effects and to increase the nutritive and functional properties of the product.

KEYWORDS

carrageenan, osmotic dehydration, ascorbic acid, volatile profile, color, anthocyanins, mechanical properties.

INTRODUCTION

Fruits are foods of high nutritional interest as a source of fiber, minerals, vitamins and antioxidants (Ayala-Zavala *et al.*, 2004). Nevertheless, their seasonal and perishable character, together with recent consumer preferences (fast food, high shelf-life products), have provoked a decrease in fresh fruit consumption, especially in the younger population. Processed products such as juices, concentrates or shakes are present in the market, but many of them have minimum fruit content, frequently substituted by several additives. For this reason, there is a great deal of interest in developing other kinds of food, such as fruit-gel products, with a high content in fresh or minimally processed fruit, where the nutritional and sensory properties (aroma, flavor, color and texture) remain close to those of fresh fruit.

Development of fruit-gel products has been extensively studied since the 80's. Several patents related to gel formulation methodology or product description can be found in the literature (Shank, 1985; Musson & Prest, 1988). But almost all of them consist of artificial fruit-based products, made from gels that have been texturized with fruit flavor (Cheney *et al.*, 1984) or by addition of fruit juice or mashed fruit (Elisabelar & Albelda, 1985; Fleck & Schindler, 1991; Jensen, 1991), or both (Kaletunc *et al.*, 1990). There are also descriptions in the literature of gels made from dehydrated fruit which are occasionally used to simulate the presence of fruit in ice creams, corn flakes, jams, etc. (Wust *et al.*, 1985; Walker & Funk, 1998; Aoki *et al.*, 2000; Gordon *et al.*, 2001).

Nevertheless, no references have been found for gelled products based on a high quantity of fresh or minimally processed fruit. In this case, with an adequate selection of the formulation (ratio fruit:gel, kind and ratio of hydrocolloid, enough transparency in order to visualize the fruit, etc.), an attractive, highly nutritional and

easy to eat product could be developed. But it is still necessary to obtain a reasonable shelf-life in terms of safety, physicochemical and sensorial stability. From this point of view, the use of partially dehydrated fruit that keeps its fresh properties may be recommendable. Osmotic dehydration (OD) with sugar solutions has been described as a suitable method for preserving fruit quality to a greater extent (Martínez-Monzó *et al.*, 2001). Osmodehydrated fruit appears to have good flavor, color, texture, and aroma (Fito *et al.*, 1995). Nevertheless, some loss of nutritional value has been described (Peiró-Mena *et al.*, 2006; Peiró-Mena *et al.*, 2007), as part of the hydrosoluble compounds flow with water from the fruit to the osmotic solution (OS). From this point of view, the use of OS as an ingredient in the fruit-gel formulation may be of great interest in terms of its final management and micronutrient recovery. Otherwise, the high biological oxygen demand (BOD) attained by the osmotic solution at the end of the process means that preliminary sanitation is necessary before being discharged as wastewater into the public sewer, thus increasing processing costs (Dalla-Rosa & Giroux, 2001). To avoid this problem, several authors proposed the use of the OS in the candying process, as a component of carbonated drinks (Dalla-Rosa & Giroux, 2001) or added to osmodehydrated fruit in order to formulate high quality and stable jams (Shi *et al.*, 1996; García-Martínez *et al.*, 2002). In this paper, the use of osmodehydrated strawberry together with the OS obtained after the OD process to formulate a strawberry-gel product is proposed. Color stability, anthocyanin content, ascorbic and citric acid contents, mechanical properties and volatile profile during storage have been considered. All of these aspects were analyzed for the osmodehydrated fruit and the gel matrix, and compared to those of the osmodehydrated fruit not placed in the gel matrix.

MATERIALS AND METHODS

Raw material and experimental design

Strawberry (*Fragaria ananassa* var. Camarosa) was purchased at a local market and visually selected on the basis of a similar degree of ripening (appearance, color, absence of damage). The raw material presented 0.912±0.002 g water/g product, 7.7±0.4 ºBrix and 0.993±0.005 water activity.

Samples were obtained by washing, removing the peduncle and longitudinally cutting each fruit into two halves. These samples were identified, weighed and submitted to the osmotic treatment, as described below. The osmodehydrated halves were stored at 5ºC for 15 days, both placed in a gel matrix (DSG: dehydrated strawberry in gel) or not placed in the gel matrix (DS: dehydrated strawberry). In both cases, 250 mL PET rectangular tubs (125x80x40 mm) provided with a PET lid were used for storage. In the case of DS samples, half a strawberry was placed in each tub; DSG samples preparation and storage is described latter on.

Water activity, ascorbic and citric acid contents, surface color, anthocyanin content, mechanical properties and volatile profile were checked at 0, 2, 5, 12 and 18 days of storage, in the osmodehydrated fruit (DSG and DS). The same analyses, except the mechanical properties, were carried out on the gel matrix (GEL). Fruit water and soluble solids contents were also measured at the same storage times. The analysis methodology is explained below.

Osmotic treatment

Osmotic dehydration was carried out by immersing the strawberry halves into a 55ºBrix commercial sucrose solution at 22ºC, at atmospheric pressure, for 6 h under

stirring conditions. The fruit-solution ratio was 1:4. From the same fruit batch, two replicates were carried out. Water content, sugar content and water activity of samples were measured after OD treatment.

Strawberry-gel product formulation

Gels were prepared from the osmotic solution obtained after OD treatment using kappa-carrageenan (1% w/w) as a gelling agent. In order to prevent mass transfer phenomena during storage, the OS was previously diluted until its water activity was balanced with that of the osmodehydrated strawberry. The procedure for gel product formulation consisted of: heating the OS to 60ºC, adding the gel agent previously wetted with ethanol and heating and stirring the mixture up to boiling until total dissolution was achieved (around 1 min). One layer of the hot solution was then poured into PET tubs and allowed to cool to 40ºC, at which point gelling starts; then one half of the osmodehydrated strawberry was placed in the centre of the tub and completely covered by a second gel layer (at 40ºC as well). Structured gels were stored at 5ºC. Half a strawberry was placed in each tub in order to better control changes taking place in the fruit during storage of the product, inspite of the fact that the optimized gel: fruit ratio for sensory acceptance of this product was 60:40 (Martínez-Navarrete *et al.*, 2007).

Analysis

Water mass fraction (x_w) was determined by vacuum drying at 60 ºC until constant weight was reached (AOAC 20103 method (AOAC, 1980)). ºBrix in the liquid phase was measured in a refractometer (ABBE ATAGO 89553 of Zeiss) at 20ºC. To this end, samples were homogenized and centrifuged to obtain the liquid phase, which

was directly measured in the refractometer. The soluble solids mass fraction (x_s) was obtained by using Eq. 1. Ascorbic acid (AA) and citric acid (CA) contents were determined by titration using the AOAC 985.33 method (AOAC, 1980). Water activity (a_w) was measured in homogenized samples by using a dew point hygrometer (Aqualab CX-2, sensitivity 0.001). Each analysis was carried out in triplicate.

$$x_S = \frac{x_W \cdot {}^{o}\mathrm{Brix}}{(100 - {}^{o}\mathrm{Brix})} \quad (1)$$

The sample's surface color was measured by means of reflectance spectra using a spectrocolorimeter (Minolta CM-3600D, Japan). CIEL*a*b* color coordinates (D65, 10º) were obtained from the spectra. Three replicates were performed on all measurements.

Anthocyanin content (ACY) was analyzed in triplicate by spectrophotometry (Spectrophotometer CECIL CE 2021). The sample (10 g) was ground, mixed with 1% HCl in methanol (100 mL) and left over night at 4ºC, as proposed by (Alarcao *et al.*, 2001). Samples were then centrifuged at 5000 rpm for 10 minutes, and filtered through Whatman No. 3 filter paper. Absorbance was measured in an aliquot at 520 nm (at which point pelargonidine 3-glucoside has the maximum absorbance). Anthocyanin concentration was correlated to absorbance by using Lambert-Beer's law (Eq. 2). Anthocyanin content was expressed as mg of pelargonidine 3-glucoside per 100 g of osmodehydrated strawberry, considering the molecular weight of this anthocyanin to be 433 g/mol (Skrede *et al.*, 1992).

$$A = a*b*c \quad (2)$$

A: absorbance

c: concentration (mol/l)

b: thickness of the medium (1cm)

a: coefficient of molar extinction ($\varepsilon_{molar,pelargonidine}$=36000 $M^{-1}cm^{-1}$ (Vicente *et al.*, 2002))

In the case of the gel matrix, both color coordinates and ACY were measured for three equidistant zones (A, B, C), A being the zone immediately surrounding the strawberry piece, C the zone directly in contact with the PET tub and B the zone between of A and C.

Mechanical response was evaluated by a puncture test carried out with a Universal Texture Analyzer (TA.XT2, Stable Micro Systems). Each half strawberry sample with the cut surface placed on the working base was analyzed, in quintuplicate, using a cylindrical 10 mm diameter punch at a penetration rate of 1.5 mm/s until 95% strain was reached. Temperature during the test was 25 ºC. The fracture force required to puncture the sample (F_{max}) was obtained from force-deformation curves. This parameter is related to the product's resistance to fracture or sample firmness (Prothon *et al.*, 2001).

Analysis of the volatile components was carried out immediately after OD treatment, and during the 15 days of storage. The combined simultaneous distillation-extraction (SDE) technique was used to isolate the volatile compounds (Godefroot *et al.*, 1981). A J&W Simultaneous Steam Distillation-Extraction Apparatus obtained from Fisher Scientific UK Ltd (Loughborough, Leics., England) was used, and the methodology described in previous papers was applied (Escriche *et al.*, 2000; Talens *et al.*, 2003). In each analysis, a 50 g sample, 50 μg of camphor (internal standard) and 100 mL of bi-distilled water were introduced into a 500 mL round-bottom flask. The flask was held in an ultrasonic bath for 5 min to totally disintegrate the sample, which was then introduced into the oil bath of the extraction equipment and heated to 90ºC. A 50 mL

heart flask containing 3 mL of pentane was introduced into a water bath at 40ºC. The steam from both flasks was condensed in the common cooled "U-tube" of the equipment. After 40 minutes of distillation, the content of the U-tube was collected, sealed and frozen to -18ºC to facilitate the separation of the organic fraction (which is liquid and has a lower density at -18ºC) where aromatic compounds are dissolved. This organic phase was concentrated in nitrogen steam up to a final volume of approximately 100 μL. Gas chromatographic analysis was conducted with a gas chromatograph/mass spectrometer (GC-MS) Finnigan TRACE MS (ThermoQuest, Austin, USA). 5 μl of each extract was injected in split mode (split ratio of 1:16) into a DB-5 fused silica capillary column (30 m; 0.32 mm i.d.; J&W Scientific, Cromlab, Spain). Helium gas (ultrahigh purity grade, 99.999%) was used as the carrier gas at a constant flow rate of 2 mL/min. The oven temperature was programmed from 40ºC to 60ºC at a ramp rate of 2ºC/min; afterwards this was increased to 260 ºC, at a ramp rate of 4ºC/min. The final holding time was 2 min. The MS fragmentation was performed by electronic impact EI+ at 70 eV. Scan mode was between 35 and 450 mass units and the scan rate was 2.5 scan/s.

Positive identifications were based on both the retention index (RI) and the mass spectra of unknown compounds compared to standard compounds (Acros Organics, Geel, Belgium). Positively identified compounds were quantified using calibration curves of peak area ratios (compound/internal standard) vs. concentration ratios (compound/internal standard) under identical chromatographic conditions. A total of 3 extracts were obtained for each sample.

Statistical analysis

Statistical treatment of the data was performed using the Statgraphics Plus 4 Software (Statgraphics, 1998). The data of each variable (color and mechanical properties, composition and volatile concentration) were analyzed with a multifactor analysis of variance (ANOVA), considering the interactions among factors. The storage medium (SM) surrounding the fruit (air or gel) and storage time (ST) were the factors for this analysis. The method used for multiple comparisons was the LSD test (least significant difference) with a significance level of $p = 0.05$. A stepwise discriminant analysis was also performed using Wilks-Lambda as the statistical selection criterion for the variables.

RESULTS AND DISCUSSION

Table 1 shows the values obtained for the water and soluble solids mass fraction and the water activity of osmodehydrated strawberry placed (DSG) or not placed (DS) in the gel matrix during storage. In addition, the evolution of GEL water activity during storage also appears in this table. Statistical analysis showed that, for DS samples, water content was not significantly affected by storage time and that although significant differences were observed in x_s, they did not show a coherent trend with the effect of storage time. In any case, the water activity of these samples did not change during storage. No exudate was observed in DS samples. DSG samples suffered significant dehydration in the first 5 days of storage, reflected by: water content loss, an increase in soluble solids and a decrease in water activity. This may be due to the difference in the water activity of the gel matrix and the DSG samples at initial storage. Despite the OS dilution carried out to ensure thermodynamic equilibrium with the dehydrated fruit, the effect of carrageenan by decreasing water

activity was not considered. As GEL water activity did not significantly change during storage, it may be supposed that DSG water loss was not completely reabsorbed by the gel matrix. In fact, an exudate was observed in the product that was 1.87 ± 0.04 g at the fifth day. This measured exudate mass corresponds to strawberry water loss at the same storage time, which could be calculated from the sample's weight and water content of samples at 0 and 5 storage days. This water loss can also explain the rise in DSG x_s values.

To analyze citric and ascorbic acid changes during storage, values of both compounds were referred to the strawberry mass at initial storage time. As can be observed on Fig. 1a, AA concentration was not significantly affected in DS samples, while DSG samples showed significant AA losses ($p<0.05$) during storage, especially in the first 48 h. A significant ($p<0.05$) increase in AA concentration in the gel matrix in the first 48 h was also observed. Concerning citric acid (Fig. 1b), a decrease in its concentration during the first 2 days of storage of both kinds of samples was detected, being more marked for DSG samples. Analysis of variance confirmed the significant differences ($p<0.05$) between DS and DSG samples, the latter ones losing a higher proportion of CA. This could indicate a certain oxidation of these compounds and a certain flow from the DSG fruit to the gel matrix during the first 48 h, coherent with the significant higher values observed in the gel matrix and the result of the mass balances. When the total amount of CA and AA present in DS sample was compared with that of the whole gel product, including the fruit and the gel matrix, lower values were obtained in the last case (data not shown).

Texture is one of the most important aspects to be considered in fruit quality, especially for fragile and perishable fruit such as strawberries (Sanz *et al.*, 1994). For this reason, mechanical properties were evaluated for DS and DSG samples. Fracture

265 force obtained from the puncture test carried out showed a similar pattern for both
266 DS and DSG samples (Fig. 1c), without significant differences ($p>0.05$) between
267 them. A sharp decrease in fracture force was observed in the first 48 h of storage, in
268 both DS and DSG samples, which could be related to the progressive loss of fruit
269 turgency caused by vital processes, leading to a structure less resistant to fracture.
270 For storage time longer than two days, F_{max} values did not show significant
271 differences ($p>0.05$).
272 Results obtained for strawberry color analysis carried out on DS and DSG samples
273 are shown in Table 2. From CIEL*a*b* color coordinates, chroma (C^*_{ab}) and hue
274 angle (h^*_{ab}) were calculated. Chromatic coordinates a* and b* showed the greatest
275 changes during storage. Statistical analysis of variance for DS and DSG samples
276 showed a significant decrease in a* and b^* coordinates with time. These changes
277 implied a significant decrease in chroma and hue angle, indicating an evolution in the
278 strawberry to more red but less pure color (more brown) during storage.
279 Color difference due to storage was calculated for DS and DSG samples (Eq. 3,
280 initial storage time denoted by subscript "o"). The obtained values remained around
281 5 units for DS samples, but increased to around 14 units for DSG samples after 15
282 days of storage.

283 $$\Delta E = \sqrt{(a^* - a^*_o)^2 + (b^* - b^*_o)^2 + (L^* - L^*_o)^2} \quad (3)$$

284 A factor that could contribute to the observed color changes could be, in addition to
285 physical changes on the fruit surface, the presence of sugar on the fruit's surface due
286 to the osmotic treatment or a certain strawberry dehydration (Contreras *et al.*, 2007).
287 On the other hand, fruit pigment losses would imply a decrease in a^* and b^* values,
288 and therefore lead to browner tones, which is, in fact, coherent with the obtained
289 results.

To analyze the contribution of these factors, anthocyanin fruit concentration was evaluated throughout storage. The concentration of anthocyanin pelargonidine 3-glucoside was related to the strawberry mass at initial storage time (Table 2). No significant differences were found between DS and DSG samples but pigment losses were detected with storage time. Nevertheless, no correlation between coordinate a^* or hue angle and anthocyanin content was found. Several works have demonstrated that pigment degradation does not always have an immediate impact on visual color changes (Skrede *et al.*, 1992). From this point of view, and taking into account the obtained x_w, x_s and ACY values, strawberry color changes seem to be more related to physical changes than to compositional ones.

Figs. 2a and 2b show, respectively, the results obtained for luminosity (L^*) and the chromatic plane a^*-b^* of the equidistant gel zones from the fruit's position inside the gel matrix, as a function of storage time. In this chromatic plane, the distance from the coordinates' origin to the sample point corresponds to chroma and the angle described from the a* axis to the sample point corresponds to hue angle. As can be seen, the closer the measured gel zone to the strawberry's position (zone A), the higher the a*, b* and chroma values and the lower the luminosity and hue angle values for all the storage times. These results are in agreement with the appearance of this zone, with a more intense red color. Multifactor analysis of variance was performed in order to evaluate how color coordinates were affected by storage time and gel zone. No significant ($p>0.05$) interactions between both factors were observed and similar color changes were obtained for each zone during storage: luminosity and hue angle significantly ($p<0.05$) decreased, whereas chroma significantly increased. As expected, these changes were more marked at initial times in zone A and progressively more apparent in zones B and C, especially during the

315 first 48 h. In any case, color coordinates reached similar values in the three studied
316 zones after 15 days of storage.
317 Analysis carried out on the gel matrix reflected the appearance of a certain quantity
318 of anthocyanins that migrate from the fruit to the gel matrix, and progressively from
319 zone A to zone B and from this to zone C (Fig. 3a). A sharp increase after 2 days was
320 observed on zone A, whereas zones B and C showed a more gradual tendency, in
321 agreement with the increasing distance from the strawberry. Multifactor analysis of
322 variance showed that observed differences in zones A, B and C, and throughout
323 storage time, were always significant ($p<0.05$). A good correlation between the a^*
324 coordinate and the anthocyanin concentration was found in this case (Fig. 3b). The
325 higher homogeneity of the gel matrix compared to the strawberry structure leads to
326 less influence on the light reflectance by the gel structure. The temperature of the gel
327 when the strawberry is placed in it (40ºC) and the cellular damage that occurs in the
328 fruit during the osmotic treatment, could be responsible for the anthocyanin diffusion
329 from the more superficial vacuoles to the gel matrix.
330 To analyze the changes that occurred in the volatile profile during storage of the
331 strawberry gel product, fifteen volatile compounds, representative of the strawberry
332 volatile fraction (Contreras *et al*., 2007; Godefroot *et al.*, 1981), were identified and
333 quantified for the fruit (DSG) and the gel matrix (GEL) at different control times. For
334 comparison, the same analysis was carried out in DS samples.
335 The fifteen major compounds quantified in the osmodehydrated fruit (Table 3) were:
336 seven esters, four alcohols, two acids, one aldehyde and one furan (2,5-dimethyl-4-
337 hydroxy-3(2H)-furanone or Furaneol®-a registered trademark of Firmenich SA). The
338 highest concentration among the identified compounds was exhibited by ethyl
339 butyrate (13 μg/g OD strawberry fruit), the ester compound family being the major

fraction. These “key compounds” (ester family) are not only important from a quantitative point of view, but have also been reported to be relevant components in the original strawberry aroma quality (Talens *et al.*, 2002; Schreier, 1980; Dirinck *et al.*, 1981; Douillard & Guichard, 1989; Larsen *et al.*, 1992; Contreras *et al.*, 2007).

The effect of storage time (ST) and storage medium (SM) (strawberry included or not included in the gel matrix), on each components concentration, was analyzed with a multifactor ANOVA. Interaction between both factors was also considered (ST x SM). It was observed that the volatile profile was more affected by storage time, as F-ratio values (Table 3) where higher for 12 of the 15 volatile compounds, especially those of trans-Hex-2-en-1-ol, isoamyl acetate and ethyl propionate compounds. As interaction appeared to be significant for all compounds, it seems that the change pathway during storage time is different depending on the storage medium.

As a result of the difficulty in evaluating the behavior of the volatile fraction considering each compound individually, the global effect of the storage medium (DSG, DS and GEL) and storage time was analyzed through two stepwise discriminant analyses (one for each factor: storage medium, and storage time), using the concentrations of the quantified compounds as variables.

First discriminant analysis showed the quantitative difference between storage mediums in terms of two functions (F1 and F2), which explains 99% of the total variance. The discriminant plot (Fig. 4a) shows that F1, which mainly explains differences (76%), separates DSG, DS and Gel samples to a great extent. DSG samples are also separated from the other two through the F2 axis (23%). Standardized coefficients of these functions (Table 4) show that ethyl octanoate (1.8087), ethyl butyrate (-1.2194) and 1-hexanol (1.1924) are the main components

of F1 and ethyl octanoate (1.8767), linalool (-1.2477) and 1-hexanol (0.8759) are the main components of F2. Hence, it seems that observed differences between samples could be explained to a great extent in terms of the concentration of these compounds.

In the discriminant analysis carried out with the factor storage time, two discriminant functions (F1 and F2) were obtained, explaining 81% of the total variance (55% F1 and 26% F2). Fig. 4b shows that F1 determined the separation of samples at day 0 from the samples at 2, 5, 8, 12 and 15 days of storage. This indicates that no significant changes occur in the strawberry volatile profile after the initial 48 h of storage, being stable for at least 15 days. From obtained standardized coefficients of these functions (Table 4), it can be seen that three volatile compounds were the most significantly involved in F1 and F2: ethyl butyrate (-10.1475 for F1 and 4.4011 for F2), 1-hexanal (4.6766 for F1 and -4.0988 for F2) and trans-Hex-2-en-1-ol (-4.4313 for F1 and 2.6771 for F2). Particular attention should be paid to the relevant effect of ethyl butyrate and 1-hexanal on the strawberry volatile profile.

CONCLUSIONS

The formulation of the described product must ensure the thermodynamic equilibrium between the dehydrated fruit and the gel matrix to avoid compositional variations. Changes in volatile profile, mechanical properties and color of the strawberry occur mainly in the first two days of storage and are not due to the presence of the gel matrix, as they also occur in the DS samples. The flux of anthocyanins from the fruit to the gel matrix leads to redness, giving the formulated product a more attractive aspect.

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FIG. 1. EVOLUTION OF: (a) ASCORBIC ACID CONTENT (AA), (b) CITRIC ACID CONTENT (CA) AND (c) FRACTURE FORCE (F_{max}) OF OSMODEHYDRATED STRAWBERRY DURING STORAGE PLACED (DSG) OR NOT PLACED (DS) IN THE GEL MATRIX. AA AND CA ARE REFERRED TO 100g OF SAMPLE AT THE BEGINNING OF STORAGE (t=0 DAYS).

FIG. 2. CHANGES IN CIEL*a*b* COORDINATES FOR EQUIDISTANT A, B AND C ZONES OF THE GEL MATRIX DURING STORAGE OF OSMODEHYDRATED STRAWBERRY INCLUDED IN THE GEL MATRIX (DSG). (a) LUMINOSITY (b) a*-b* CHROMATIC PLANE; NUMBERS CORRESPOND TO STORAGE DAYS.

FIG. 3. (a) CHANGES IN ANTHOCYANIN CONTENT IN A, B, AND C EQUIDISTANT ZONES OF THE GEL MATRIX DURING STORAGE; (b) RELATIONSHIP BETWEEN ANTHOCYANIN CONTENT AND HUE ANGLE IN A, B AND C EQUIDISTANT ZONES OF THE GEL MATRIX.

FIG. 4. DISCRIMINANT FUNCTIONS PLOTS FOR: (a) STORAGE MEDIUM (b) DAYS OF STORAGE.

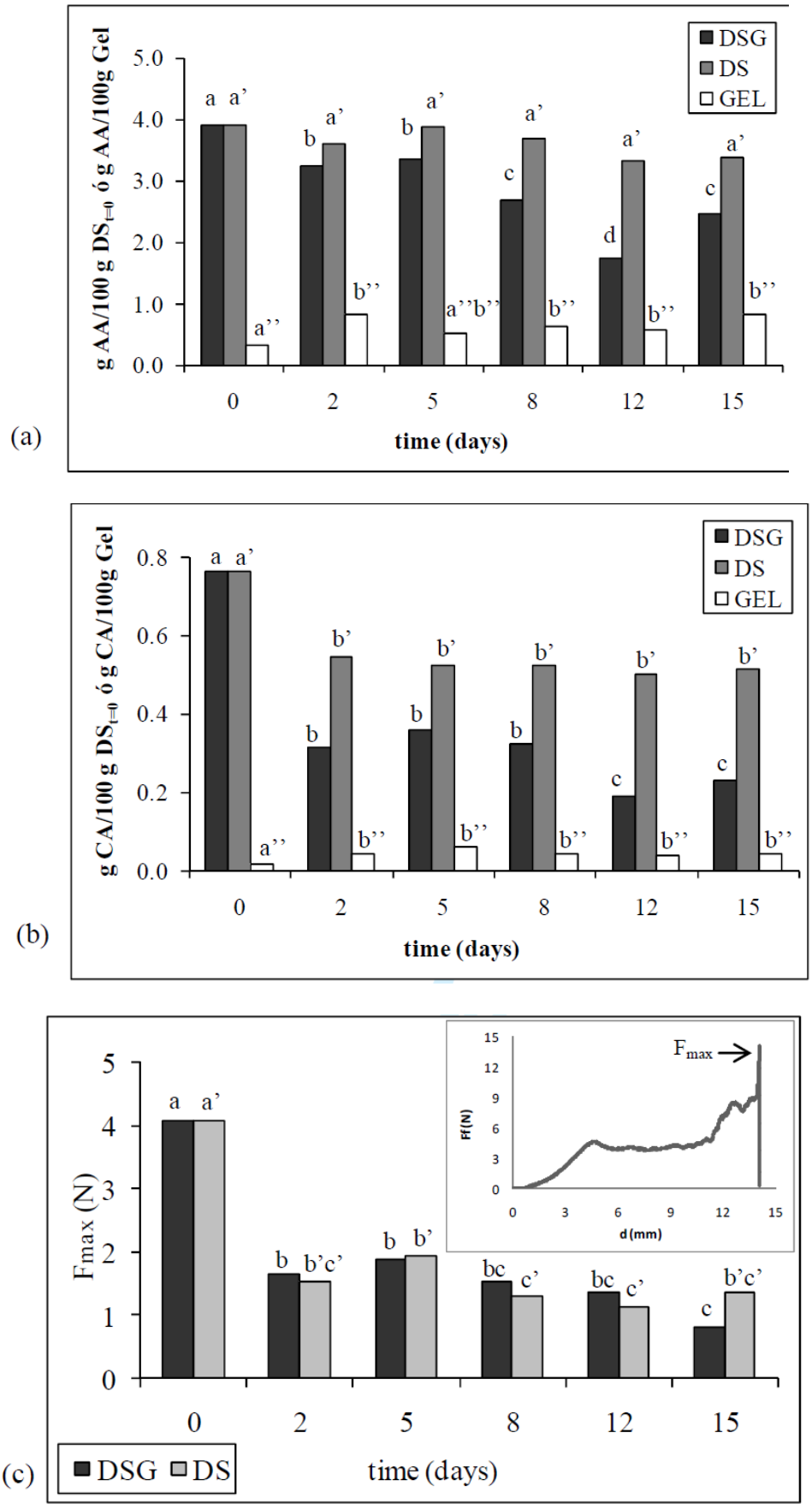
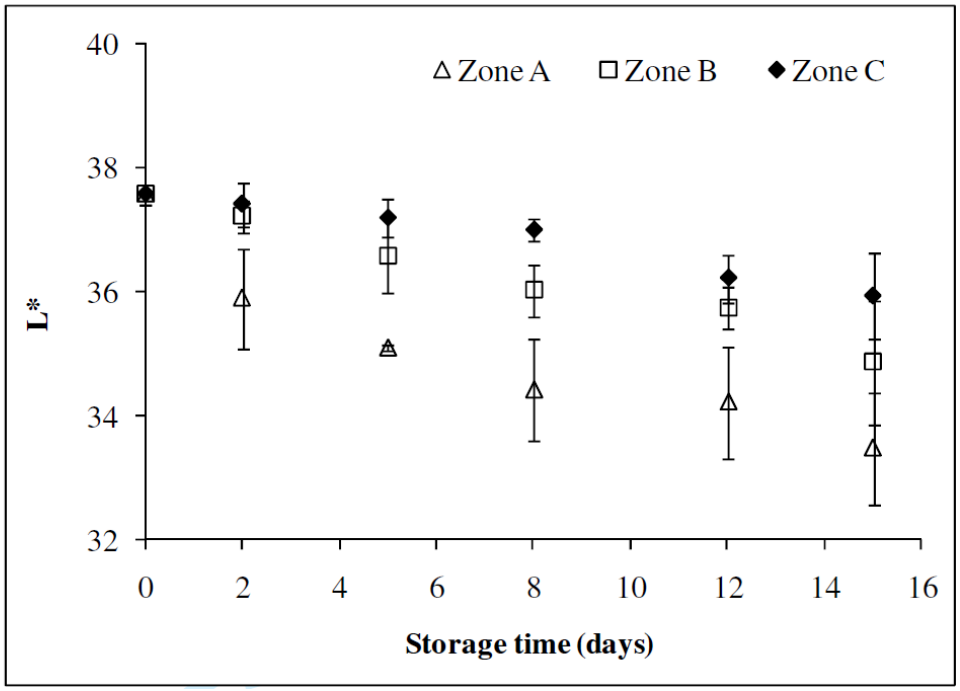

(a)
g AA/100 g DS$_{t=0}$ ó g AA/100g Gel
DSG
DS
GEL
time (days)
(b)
g CA/100 g DS$_{t=0}$ ó g CA/100g Gel
DSG
DS
GEL
time (days)
(c)
Fmax (N)
Fmax
Ff(N)
d (mm)
DSG
DS
time (days)

FIG. 1.

(a)


Zone A
Zone B
Zone C
L*
Storage time (days)
40
38
36
34
32
0
2
4
6
8
10
12
14
16

(b)

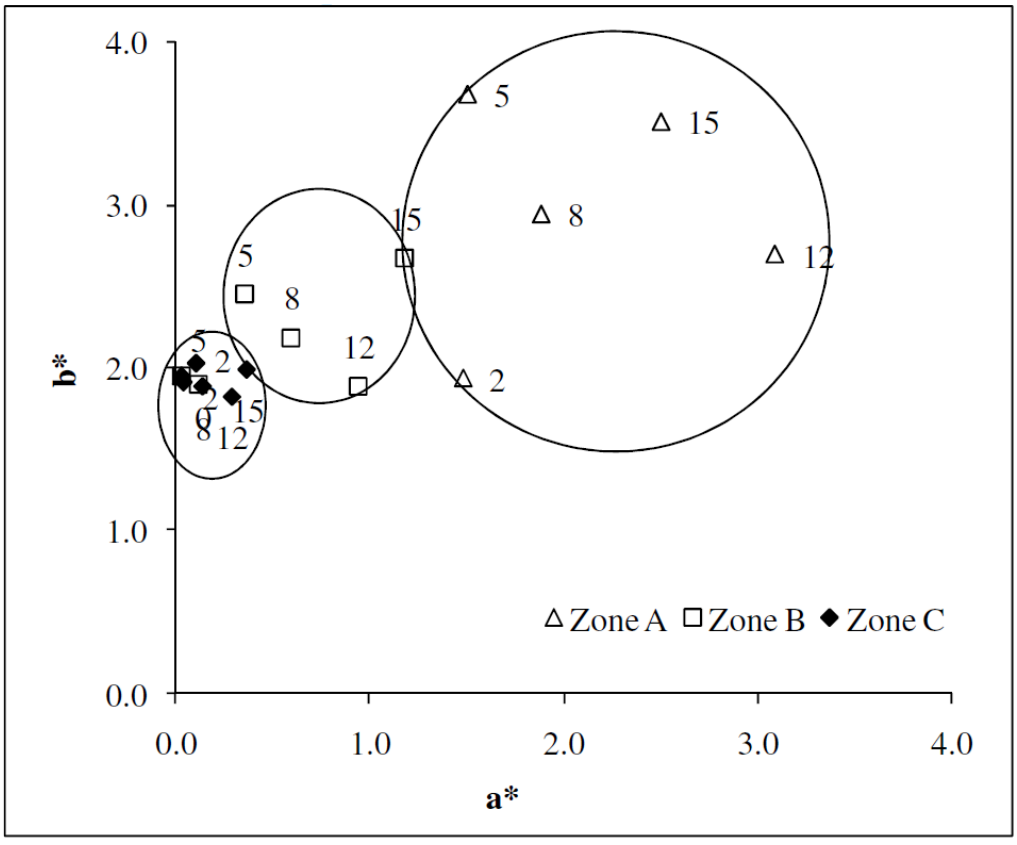
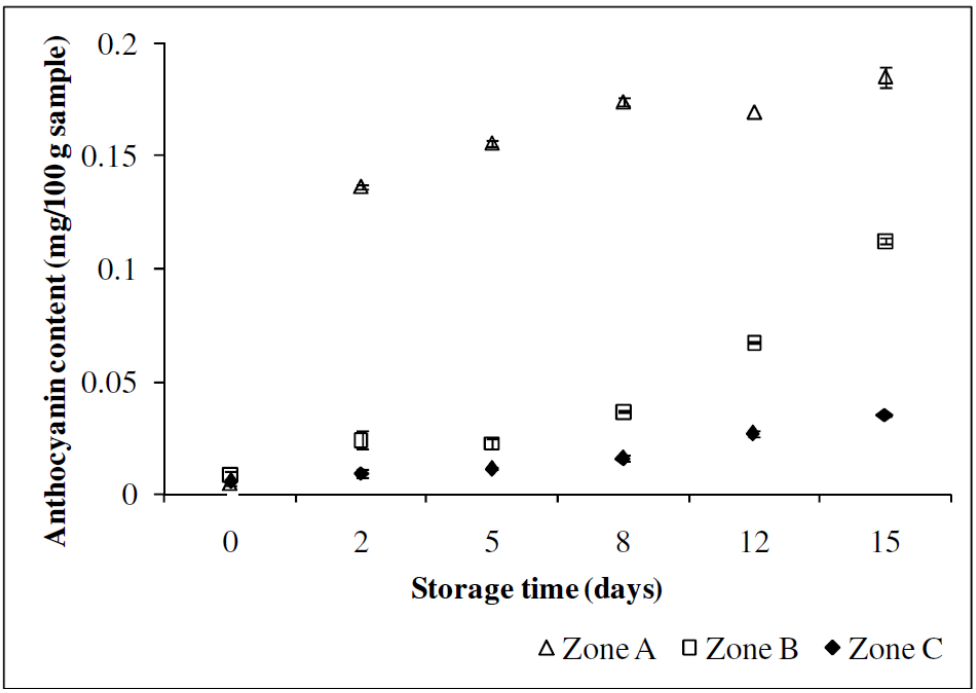

b*
a*
Zone A
Zone B
Zone C
4.0
3.0
2.0
1.0
0.0
0.0
1.0
2.0
3.0
4.0

FIG. 2

(a)


Anthocyanin content (mg/100 g sample)
0.2
0.15
0.1
0.05
0
0
2
5
8
12
15
Storage time (days)
Zone A
Zone B
Zone C

(b)

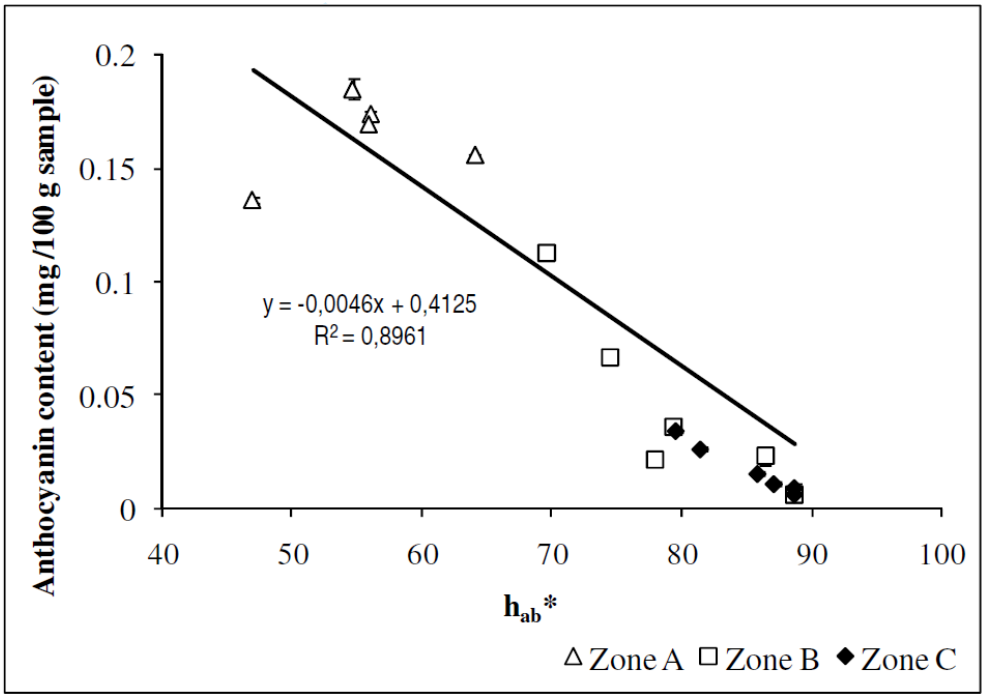
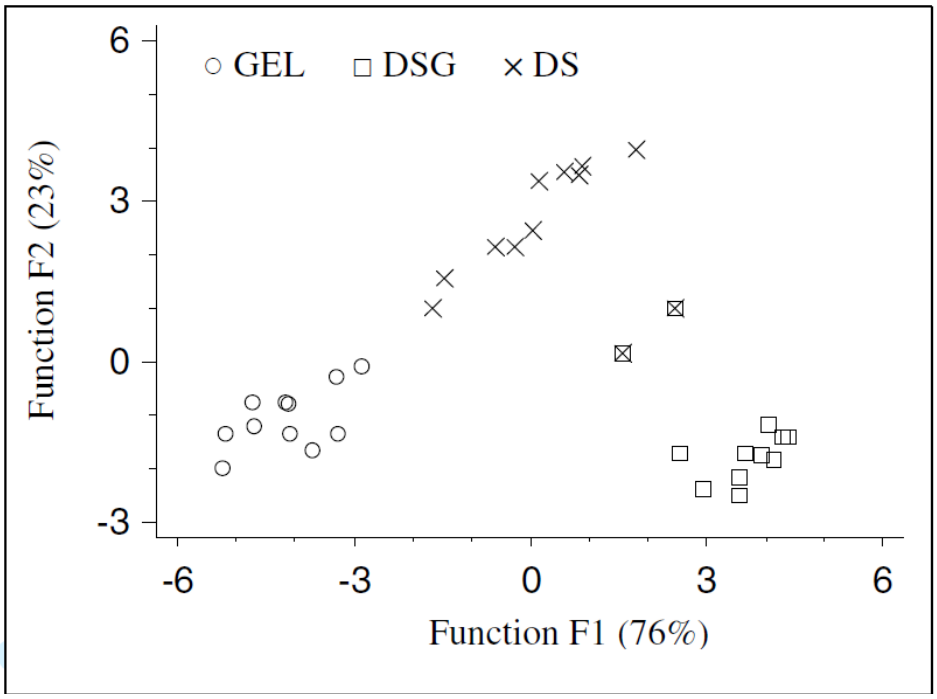

Anthocyanin content (mg/100 g sample)
0.2
0.15
0.1
0.05
0
y = -0,0046x + 0,4125
R2 = 0,8961
40
50
60
70
80
90
100
hab*
Zone A
Zone B
Zone C

FIG. 3

(a)


○ GEL □ DSG × DS
Function F2 (23%)
Function F1 (76%)
6
3
0
-3
-6
-3
0
3
6

(b)

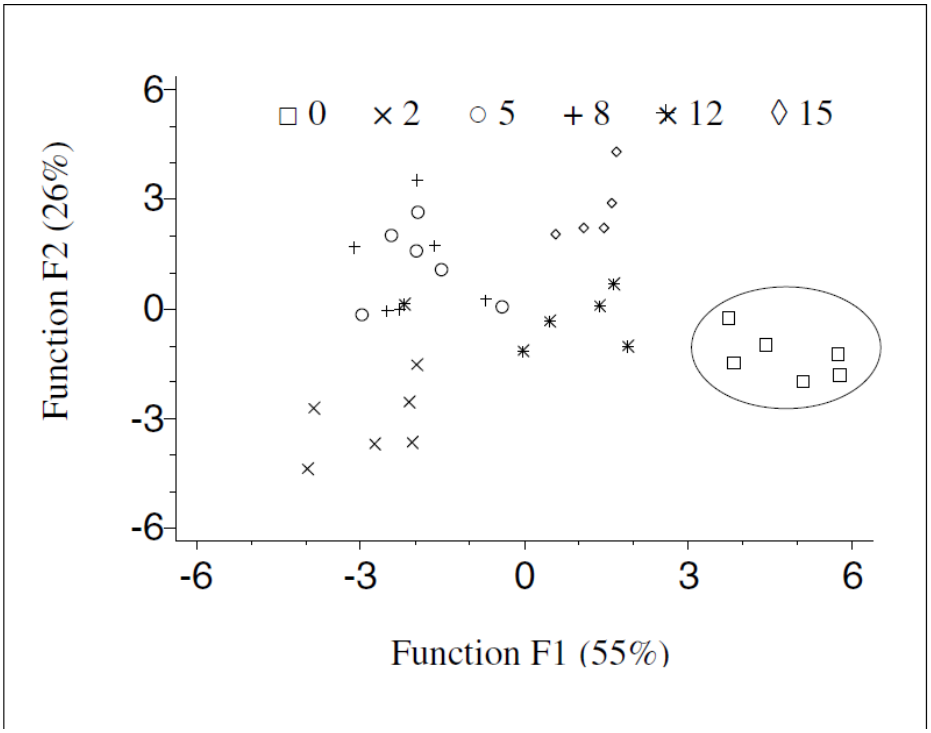

□ 0 × 2 ○ 5 + 8 ✳ 12 ◊ 15
Function F2 (26%)
Function F1 (55%)
6
3
0
-3
-6
-6
-3
0
3
6

FIG. 4

TABLE CAPTIONS

TABLE 1.

MEAN VALUES OF WATER MASS FRACTION (x_w), WATER ACTIVITY (a_w) AND SOLUBLE SOLIDS MASS FRACTION (x_s) OF OSMODEHYDRATED STRAWBERRY DURING STORAGE PLACED (DSG) AND NOT PLACED (DS) INSIDE THE GEL MATRIX; WATER ACTIVITY OF THE GEL MATRIX (GEL).

	x_w		a_w			x_s	
Days	DS	DSG	DS	DSG	GEL	DS	DSG
0	0.801 ± 0.003 a	0.801 ± 0.003 b	0.982 a	0.982 a	0.974 a	0.146 ± 0.005 c	0.146 ± 0.005 a
2	0.79 ± 0.04 a	0.759 ± 0.014 ab	0.980 a	0.972 b	0.972 a	0.132 ± 0.003 a	0.149 ± 0.004 a
5	0.81 ± 0.03 a	0.715 ± 0.003 a	0.977 a	0.967 b	0.979 a	0.138 ± 0.006 ab	0.161 ± 0.005 b
8	0.819 ± 0.001 a	0.728 ± 0.009 a	0.985 a	0.969 b	0.971 a	0.140 ± 0.002 bc	0.199 ± 0.003 c
12	0.79 ± 0.06 a	0.709 ± 0.004 a	0.980 a	0.969 b	0.969 a	0.168 ± 0.003 d	0.222 ± 0.007 d
15	0.78 ± 0.05 a	0.706 ± 0.004 a	0.981 a	0.966 b	0.970 a	0.173 ± 0.003 d	0.219 ± 0.004 d

Within each column, values with the same following letter do not differ significantly from each other ($p<0.05$)

TABLE 2.

CHANGES IN CIEL*a*b* COORDINATES, CHROMA (C^*_{ab}), HUE ANGLE (h^*_{ab}) AND ANTHOCYANIN CONTENT (ACY) OF OSMODEHYDRATED STRAWBERRY DURING STORAGE PLACED (DSG) OR NOT PLACED (DS) IN THE GEL MATRIX.

Days	Sample	L*	a*	b*	C^*_{ab} [(a)]	h^*_{ab} [(b)]	ACY
0		29 ± 2 a	23.4 ± 1.5 c	10.7 ± 1.3 d	26 ± 2 d	24 ± 3 b	18.25 ± 1.12 b
2		33.9 ± 0.4 b	20.6 ± 1.2 bc	6.72 ± 0.07 c	22 ± 2 c	18.1 ± 1.9 a	16 ± 2 ab
5	DSG	33.0 ± 1.8 ab	18.3 ± 1.3 b	6.9 ± 0.7 c	19.6 ± 1.3 bc	21 ± 2 ab	14.9 ± 0.6 a
8		34 ± 2 ab	14.7 ± 0.6 a	4.94 ± 0.06 b	15.5 ± 0.6 a	18.6 ± 0.5 a	15.6 ± 2.6 ab
12		32.2 ± 0.6 ab	17.7 ± 0.5 b	5.4 ± 0.6 b	18.5 ± 0.6 b	16.8 ± 1.3 a	14.7 ± 1.8 a
15		31.8 ± 1.8 ab	12.1 ± 0.5 a	3.5 ± 0.5 a	12.6 ± 0.4 a	16 ± 2 a	13.9 ± 1.9 a
0		29 ± 2 a	23.4 ± 1.5 b	10.75 ± 1.3 c	26 ± 2 b	24 ± 3 d	18.25 ± 1.12 b
2		28.50 ± 0.12 a	21.1 ± 1.5 a	6.2 ± 0.5 ab	21.9 ± 1.6 a	16.5 ± 0.3 ab	14.8 ± 0.7 ab
5	DS	29.1 ± 1.9 a	19.5 ± 1.4 a	5.40 ± 0.07 a	20.2 ± 1.3 a	15.5 ± 1.2 a	14.9 ± 2.5 ab
8		32.9 ± 1.9 b	20.6 ± 0.8 a	8.91 ± 0.16 bc	22.4 ± 0.8 a	23.4 ± 0.4 c	13.1 ± 2.4 a
12		30.5 ± 0.9 ab	20.8 ± 1.6 a	8.6 ± 0.9 bc	22.53 ± 1.15 a	22 ± 2 c	12.42 ± 2.01 a
15		28.75 ± 0.08 a	20.1 ± 1.1 a	5.20 ± 0.14 a	20.67 ± 1.06 a	14.6 ± 0.3 a	11.09 ± 0.12 a

Values expressed as mean ± standard deviation. Within each column, values with the same following letter do not differ significantly from each other ($p<0.05$)

[(a)] $C^*_{ab} = \sqrt{a^{*2} + b^{*2}}$

[(b)] $h^*_{ab} = \text{arctg}\frac{b^*}{a^*}$

TABLE 3.

MEAN CONCENTRATION VALUES OF THE QUANTIFIED VOLATILE COMPOUNDS IN THE OSMODEHYDRATED STRAWBERRY FRUIT (DS), AND ANOVA F-RATIO FOR EACH OF THE 2 FACTORS AND THEIR RESPECTIVE INTERACTIONS IN THE OBSERVED VARIABLES (VOLATILE COMPOUNDS).

		(µg/g sample)	ANOVA F-Ratio		
Compounds		DS	SM[a]	ST[b]	SM x ST
Esters	Ethyl propionate	0.052 ± <0.01	14.9[c]	205.8[c]	22.3[c]
	Isobutyl acetate	<0.01 ± <0.01	29.4[c]	95.1[c]	29.4[c]
	Ethyl butyrate	13 ± 3	6.9[c]	52.8[c]	4.7[d]
	Isoamyl acetate	0.75 ± 0.05	5.4[d]	271.8[c]	8.7[c]
	Ethyl hexanoate	<0.01 ± <0.01	24.1[c]	12.2[c]	5.4[c]
	Hexyl acetate	1.8 ± 0.2	4.0[c]	173.4[c]	6.0[c]
	Ethyl octanoate	0.55 ± 0.18	8.7[c]	51.9[c]	3.1[c]
Alcohols	1-Hexanol	0.54 ± 0.06	10.2[c]	28.8[c]	4.8[d]
	trans-Hex-2-en-1-ol	<0.01 ± <0.01	123.5[c]	470.2[c]	123.5[c]
	1-Heptanol	<0.01 ± <0.01	64.7[c]	64.7[c]	64.7[c]
	Linanool	0.51 ± 0.14	8.8[c]	48.1[c]	5.0[d]
Acids	Isobutyric acid	<0.01 ± <0.01	25.7[c]	7.2[d]	18.1[c]
	Hexanoic acid	0.17 ± 0.03	3.0[c]	6.9[d]	2.6[c]
Aldehyde	1-Hexanal	8 ± 2	6.9[c]	52.8[c]	4.7[d]
Furan	Furaneol	2.3 ± 0.5	13.1[c]	112.8[c]	4.2[d]

[a]SM: storage medium; [b]ST: storage time, [c] $p < 0.001$; [d] $p < 0.01$; [e] $p < 0.05$

TABLE 4.

STANDARDIZED DISCRIMINANT FUNCTION COEFFICIENTS.

Factors	**SM**[a]		**ST**[b]	
Compounds	**Function F1**	**Function F2**	**Function F1**	**Function F2**
1-Hexanol	1.1924	0.8759	0.6907	0.0093
Hexanoic acid	-0.6203	0.0880	0.4902	-0.7489
Isobutyric acid	0.2966	-0.1327	0.4425	0.7711
Hexyl acetate	1.1768	0.4764	3.5064	0.2614
Isoamyl acetate	0.6886	-0.2689	-0.8008	0.9153
Isobutyl acetate	0.2604	-0.0676	1.6228	-1.3520
Ethyl butyrate	-1.2194	-0.8639	-10.1475	4.4011
Furaneol	0.6209	0.0879	-1.8219	-1.9545
1-Hexanal	-0.7140	-0.5059	4.6766	-4.0988
Ethyl hexanoate	-0.9504	0.1626	-3.7143	0.5916
Linalool	-0.5021	-1.2477	2.7350	-1.8886
Ethyl octanoate	1.8087	1.8767	2.4779	1.8022
Ethyl propionate	-0.4425	-0.1593	2.4233	-0.4684
trans-Hex-2-en-1-ol	-0.6494	-0.4686	-4.4313	2.6771

[a]SM: storage medium; [b]ST: storage time