DOI: 10.12957/demetra.2018.31920

Sensory acceptability and physico-chemical characteristics of dehydrated strawberries with different treatments

Aceitabilidade sensorial e características físico-químicas de morangos desidratados com diferentes tratamentos

Vanessa Alves[1]
Francielle do Rocio da Luz[1]
Kélin Schwarz[2]
Renata Leia Demario Vieira[1]
Gabriela Datsch Bennemann[1]
Juliano Tadeu Vilela de Resende[3]

[1] Universidade Estadual do Centro Oeste, Departamento de Nutrição. Guarapuava, PR, Brasil.

[2] Universidade Federal do Triângulo Mineiro, Departamento de Nutrição. Uberaba, MG, Brasil.

[3] Universidade Estadual do Centro Oeste, Departamento de Agronomia. Guarapuava, PR, Brasil.

Correspondence
Kélin Schwarz
E-mail: kelinschwarz@hotmail.com

Abstract

Dehydration is a viable alternative to using strawberries that are not proper for marketing because of their form, size or color. This study aimed to evaluate the sensory acceptability and physico-chemical characteristics of dehydrated strawberries with different treatments. The treatments were applied before drying at 60°C and consisted of: 1 - 60% sucrose + ascorbic acid; 2 - 60% sucrose + citric acid; 3 - 60% sucrose + pectin; 4 - 80% sucrose + ascorbic acid; 5 - 80% sucrose + citric acid; 6 - 80% sucrose + pectin and 7 - control treatment (without addition of sucrose and/or ingredient). The treatments were evaluated by sensory analysis with hedonic scale with untrained judges. The content of soluble solids, titratable acidity, pH, color, ascorbic acid, anthocyanins, and phenolic compounds of dehydrated fruits was evaluated. The osmotic treatments of 80% sucrose + ascorbic acid or pectin were well accepted by the testers and were better than the control treatment. The soluble solids content varied among treatments and was higher for strawberries treated with 80% sucrose + pectin, which also had a higher soluble solids/titratable acidity ratio. The content of phenolic compounds, anthocyanins and ascorbic acid was higher for the treatments 80% sucrose + pectin or ascorbic acid or citric acid, which also showed a more intense red color. Dehydrated strawberry with pretreatment 80% sucrose + ascorbic acid or pectin seemed to be a good option for adding value to this fruit, since it had a good acceptance and maintenance of bioactive compounds.

Keywords: Fragaria x ananassa Duch. Osmotic dehydration. Sensory analysis. Bioactive compounds. Preservation.

Resumo

A desidratação é uma alternativa viável para utilizar morangos que não possuem formato, tamanho ou cor adequados para a comercialização. Este estudo teve como objetivo avaliar a aceitação sensorial e características físico-químicas de morangos desidratados com diferentes tratamentos. Os tratamentos utilizados foram aplicados antes da secagem em estufa a 60°C e consistiram em 1 - 60% sacarose + ácido ascórbico; 2 - 60% sacarose + ácido cítrico; 3 - 60% sacarose + pectina; 4 - 80% sacarose + ácido ascórbico; 5 - 80% sacarose + ácido cítrico; 6 - 80% sacarose + pectina e 7 - tratamento controle (sem adição de sacarose e/ou ingrediente). Os tratamentos foram avaliados por meio de análise sensorial com escala hedônica com julgadores não treinados. Foram avaliados o teor de sólidos solúveis, acidez titulável, pH, coloração, ácido ascórbico, antocianinas e compostos fenólicos dos frutos desidratados. Os tratamentos osmóticos de 80% sacarose + ácido ascórbico ou pectina foram bem aceitos pelos provadores e mostraram-se melhores que o tratamento controle. O teor de sólidos solúveis variou entre os tratamentos e foi maior para os morangos tratados com 80% sacarose + pectina, também apresentando maior relação sólidos solúveis/acidez titulável. O teor de compostos fenólicos, antocianinas e ácido ascórbico foi maior para os tratamentos 80% sacarose + pectina ou ácido ascórbico ou ácido cítrico, os quais também apresentaram coloração vermelha mais intensa. O morango desidratado com pré-tratamento 80% sacarose + ácido ascórbico ou pectina mostrou-se boa opção de agregação de valor a essa fruta, visto que apresentou boa aceitação e manutenção de compostos bioativos.

Palavras-chave: Fragaria x ananassa Duch;. Desidratação osmótica. Análise sensorial. Compostos bioativos. Conservação.

Introduction

Strawberry (Fragaria x ananassa Duch) is a highly valued fruit and one of the most consumed in the world; however, it is quite delicate and highly perishable since it is poorly resistant after harvest.[1,2] This fruit is a rich source of bioactive compounds, such as vitamin C, carotenoids and phenolic compounds (phenolic acids, flavonoids and anthocyanins).[3,4]

The commercial interest in strawberry is great in many countries due to its color, aroma, flavor and nutritional properties, which make it a product of high commercial value and much appreciated by consumers.[5] In Brazil, national production reaches 105 thousand tons per year, most of it obtained on small farms.[6] However, it is estimated that about 40% of this production is lost due to the high perishability of the fruit.[7,8]

The strawberry market is quite attractive, since in addition to the primary production, for the consumption of fresh fruits, this crop is of great importance for the agribusiness, being raw material for the production of ice cream, dairy beverages, sweets, liqueurs, jellies, among others.[9] The commercialization of fresh fruits, however, has as a limitation the rapid loss of post-harvest quality,[10,11] being a fresh strawberry's life of approximately five days when kept at low temperatures (0 to 4 °C).[2,12]

Considering the perishability of strawberry and the fact that it may be stored for a few days,[13] there is a need to use adequate technology to improve its preservation and shelf life. One of the preservation options is the drying process, which may be accomplished by several methods, which remove part of the water from the food, reducing deterioration by microorganisms and chemical and enzymatic changes.[14]

Dehydration is a technique which consists in the removal of water by evaporation, with heat and mass transfer, in which the solid to be dried is exposed to a stream of hot air flowing continuously and thus moisture is removed.[15] Decreasing the amount of water by drying reduces biological activity and post-harvest physico-chemical changes of the final product, improving stability. This process still adds value to the finished product and reduces waste.[16]

Dehydrated foods are widely accepted commercial products because they have increased shelf life without losing much of their organoleptic and nutritional properties.[17] According to the Instituto Brasileiro de Geografia e Estatística (IBGE - Brazilian Institute of Geography and Statistics),[18] the production of dried or lyophilised products jumped from 11.1 million to 26.8 million kilograms between 2010 and 2011, showing strong growth in the sector. However, when subjected to the drying process, the fruits may lose compounds of nutritional interest or even important physico-chemical characteristics.

In this sense, and due to the constant need for innovation to strengthen family agriculture in food supply, the objective of this study was to develop dehydrated strawberries with different treatments and to evaluate their sensory acceptability and physico-chemical characteristics in order to determine the best treatment for a final quality product and with less loss of compounds of nutritional interest.

Material and Methods

The strawberries were obtained from a local commerce in Guarapuava-PR. Those that were in the mature stage, characterized by bright red color, were used.

Elaboration of dehydrated strawberries

The fruits were selected, the crown (green part) was removed and they were washed in running water and then immersed in sodium hypochlorite solution (150 mg L^{-1}) for 15 minutes for disinfection. Then, they were dried at room temperature. After being cleaned, the samples were cut into slices with the aid of a stainless steel knife in order to facilitate the drying.

The drying process was carried out at the Laboratory of Vegetable Production - Olericulture, from the Department of Agronomy of the Universidade Estadual do Centro-Oeste (State University of the Central-West), with the aid of a drying oven with forced circulation of air.

Treatments

One and a half kg of strawberries was selected for each treatment. The treatments consisted of osmotic dehydration with sucrose solution at concentrations of 60% and 80% for two hours, followed by addition of one of the preserving ingredients: citric acid, ascorbic acid or pectin.

After these procedures, the fruits were placed in trays and oven dried at 60°C for six hours or until a product with a moisture content of less than 25% was obtained.[19] Thus, seven treatments were obtained, as described in detail below:

- **T1:** osmotic dehydration with 60% sucrose solution + immersion in 1% ascorbic acid for 2 minutes + drying at 60°C for 6 hours;
- **T2:** osmotic dehydration with 60% sucrose solution + immersion in 1% citric acid for 2 minutes + drying at 60°C for 6 hours;
- **T3:** osmotic dehydration with 60% sucrose solution + immersion in 2% pectin for 15 minutes + drying at 60°C for 6 hours;
- **T4:** osmotic dehydration with 80% sucrose solution + immersion in 1% ascorbic acid for 2 minutes + drying at 60°C for 6 hours;
- **T5:** osmotic dehydration with 80% sucrose solution + immersion in 1% citric acid for 2 minutes + drying at 60°C for 6 hours;

- **T6:** osmotic dehydration with 80% sucrose solution + immersion in 2% pectin for 15 minutes + drying at 60°C for 6 hours;
- **T7:** dehydration of the fruits only by drying at 60°C for 6 hours (control treatment).

The solutions of sucrose, citric acid, ascorbic acid and pectin were prepared with distilled water and respecting the appropriate conditions of hygiene and good manufacturing practices.

After oven-drying, the strawberries were packed in plastic bags properly closed and identified until the moment of the analyses.

Sensory analysis

Sensory tests were conducted at the Sensory Analysis Laboratory of the Department of Food Engineering of the Universidade Estadual do Centro-Oeste (State University of the Central-West), in individual booths with white lighting.

Participating in the study were 68 untrained testers, among students, professors and employees of the institution, of both genders, with a minimum age of 18 years and without any subordination link with the researchers. For their recruitment, an approach was made by the researchers via an oral invitation.

All participants received the seven dehydration treatments of the strawberries and evaluated the samples regarding the attributes color, flavor, texture, aroma and overall acceptance, using a nine-point structured hedonic scale, varying from I extremely disliked it (score 1) to I extremely liked it (score 9), according to Dutcosky's[20] methodology. For the purchase intent test, a five-point scale was anchored at its extremes with the terms: 1 – I would certainly not buy it to 5 – I would certainly buy it.

Each judge received a piece of each sample in white plastic plates, coded with three-digit numbers, in a randomized design, accompanied by water to be used between each tasting. The samples were offered to the judges in sequential monadic form.

Acceptability index (AI)

The AI calculation of the treatments was performed according to the formula: *AI (%) = A x 100/B (A = mean score obtained for the product, B = maximum score given to the product)*.[20] The treatment was considered well accepted when the AI was higher than or equal to 70%.[21]

Titratable acidity

The titratable acidity was performed in triplicate and according to the Association of Official Analytical Chemists (AOAC),[22] through titration with 0.1 mol L^{-1} sodium hydroxide up to pH 8.1. The results were expressed in grams of 100 g^{-1} citric acid sample.

Soluble solids

The soluble solids content was verified in triplicate in bench refractometer with two to three drops of the sample filtrate. The results were expressed in °Brix. The filtrate was obtained by the solubilization of the dehydrated samples in a known volume of distilled water (ratio 1:3, m/v).

Solid soluble/titratable acidity ratio

The SS/TA ratio was calculated from the data obtained for the content of soluble solids and titratable acidity.

pH

The pH was determined in triplicate, at room temperature with the aid of a pH meter in samples diluted in water.

Phenolic compounds and anthocyanins

The content of phenolic compounds was determined by the Folin-Ciocalteu method, as described by Woisky & Salatino,[23] in a spectrophotometer at 740 nm. The results were expressed in mg of gallic acid per 100 grams of sample.

The anthocyanins content was determined by the differential pH method described by Giusti & Wrolstad.[24] The method is based on two buffer systems, 0.025 M potassium chloride, pH 1.0 and 0.4 M sodium acetate, pH 4.5. The samples were analyzed at 510 and 700 nm in a spectrophotometer, and the results expressed in mg of cyanidin-3-glycoside per 100 grams of sample.

The extracts for the analysis of the phenolic compounds and anthocyanins were prepared through percolation of the sample homogenized with ethanol solution: water (80:10, v/v) in the proportion 1:15 (sample:solvent). These procedures were performed in a low-light environment.

The extraction was carried out in a stirring table at room temperature for 30 minutes at 135 rpm followed by a water bath at 37°C for 30 min. The resulting extract was centrifuged at 2235.7 g for 10 minutes. The supernatant was then filtered and used for the analyses.

Ascorbic acid

The ascorbic acid content was determined by the titration method of AOAC[22] modified by Benassi & Antunes,[25] and the results were expressed in mg of ascorbic acid per 100 grams of sample.

Coloring

The color changes were determined using a Minolta colorimeter with illuminant D65. The values of L*, a* and b* were obtained; in which L represents the luminosity, a* defines the transition from green (-a*) to red (+a*) and b* represents the transition from blue (-b*) to yellow (+b*). The values of the hue angle (°H) were calculated according to the formula: $°H = tg\text{-}1(b^*/a^*)$.

Readings were performed at three different points of the samples. The analysis was carried out in a place with high luminosity and in triplicate.

Statistical analysis

The statistical analysis was performed using the SAS 9.0 software. The data were submitted to analysis of normality (Shapiro-Wilk) and homogeneity of variances (Box-Cox) and later submitted to analysis of variance (ANOVA).

The data obtained from the sensory analysis were submitted to ANOVA in randomized blocks, in which each tester represents a block. The analyses of physico-chemical characterization were performed in a completely randomized design with three replications. When the results of the *F*-test (ANOVA) were significant, the means were compared by the Tukey's test ($p<0.05$).

Ethical issues

This study was approved by the Research Ethics Committee of the Universidade Estadual do Centro-Oeste (State University of the Central-West), under opinion number 1,639,854/2016. The exclusion criteria were: to be under 18 years old, to claim some allergy to the products that were evaluated or to not allow the disclosure of their results, nor their use in the present study.

Results and Discussion

Table 1 shows the results of the sensory evaluation of dehydrated strawberries with different treatments.

Table 1. Means of affective sensory tests, purchase intention (means ± standard deviation) and acceptability index (AI) performed for the dehydrated strawberries under different treatments[1]. Guarapuava-PR, 2016.

Treatments	Attributes					
	Color	Aroma	Flavor	Texture	Overall acceptance	Purchase intention
Control	5.7 ± 1.4 c	6.6 ± 1.9 ab	6.1 ± 1.9 a	6.4 ± 2.2 ab	6.3 ± 1.7 bc	3.0 ± 1.2 d
AI (%)	71.7	73.0	68.0	71.1	70.1	59.4
80% + citric acid	6.1 ± 1.8 bc	6.8 ± 2.1 ab	6.1 ± 2.4 a	6.2 ± 2.4 ab	6.4 ± 2.1 abc	3.4 ± 1.3 bcd
AI (%)	67.5	75.2	67.8	69.1	70.9	67.1
80% + ascorbic acid	7.5 ± 1.7 a	7.2 ± 1.7 a	6.8 ± 1.9 a	7.0 ± 1.9 a	7.2 ± 1.7 a	4.5 ± 0.7 a
AI (%)	83.8	80.1	75.8	78.3	79.7	90.3
80% + pectin	7.7 ± 1.4 a	7.3 ± 1.5 a	6.7 ± 1.6 a	6.8 ± 1.8 a	7.0 ± 1.3 ab	3.7 ± 1.1 b
AI (%)	85.3	80.7	74.8	75.0	77.9	74.1
60% + citric acid	6.2 ± 1.8 bc	6.1 ± 2.1 b	6.1 ± 2.0 a	5.5 ± 2.3 b	6.1 ± 1.8 c	3.1 ± 1.0 cd
AI (%)	68.5	68.0	67.6	61.1	68.0	62.6
60% + ascorbic acid	6.6 ± 1.8 b	6.3 ± 1.9 b	6.5 ± 1.6 a	6.6 ± 1.9 a	6.4 ± 1.7 abc	3.5 ± 1.3 bcd
AI (%)	73.4	70.4	71.7	73.9	71.2	69.7
60% + pectin	8.3 ± 1.2 a	6.8 ± 1.7 ab	6.5 ± 1.7 a	6.4 ± 2.1 ab	6.6 ± 1.6 abc	3.7 ± 1.1 bc
AI (%)	91.7	75.8	72.2	71.4	73.9	73.2

[1] Different letters in the column indicate significant difference by the Tukey's test ($p<0.05$); 80% = 80% sucrose; 60% = 60% sucrose.

For the color attribute, the treatments 80% sucrose + ascorbic acid, 80% sucrose + pectin and 60% sucrose + pectin were the most accepted, with scores 7.5, 7.7 and 8.3, respectively, with no significant difference among them ($p>0.05$). On the other hand, the least accepted treatment was the control, which received a mean score of 5.7 and AI of 71.7%. However, the control treatment did not differ from the 80% sucrose + citric acid treatment and from the 60% sucrose + citric acid treatment regarding color. This difference among the treatments is related to the fact that the color influences the acceptability of the product[20] and also because of the ingredients such as ascorbic acid and pectin, which, when added, reduced the darkening reactions of the fruits, probably preserving the color.[26] In addition, the treatments with higher color scores also had higher contents of anthocyanins and phenolic compounds (table 3). It is known that these compounds are related to the strawberry color,[27] and when present in larger quantities, they may intensify the color favoring this sensory attribute.

In relation to the aroma attribute, only one of the treatments received AI lower than the one considered with good sensory acceptance (70%), which was the treatment 60% sucrose + ascorbic acid with AI of 68% and score 6.1. The highest score was from the treatment 80% sucrose + pectin, with 7.3 and AI of 80.75.

Regarding taste, the treatment 80% sucrose + ascorbic acid obtained a score of 6.8, with AI of 75.8%, being the most sensorially accepted. On the other hand, the treatments control, 80% sucrose + citric acid and 60% sucrose + citric acid received low scores and were the least accepted. Based on the texture scores, the treatment 60% sucrose + citric acid obtained the lowest scores, differing only from the treatments 80% sucrose + ascorbic acid, 80% sucrose + pectin and 60% sucrose + ascorbic acid.

The treatment with the greatest overall acceptance was 80% sucrose + ascorbic acid, with a mean of 7.2 and AI of 79.7%. However, this treatment did not statistically differ from the treatments 80% sucrose + citric acid, 80% sucrose + pectin, 60% sucrose + ascorbic acid and 60% sucrose + pectin. On the other hand, the dehydrated strawberries with the lowest overall acceptance were those treated with 60% sucrose + citric acid, with a mean of 6.1 and AI of 68%.

Regarding purchase intention, the treatment with the highest score was 80% sucrose + ascorbic acid, with a mean score of 4.5 and AI of 90.3%. On the other hand, the lowest score was the control, with a mean of 3.0 and AI of 59.4%.

In general, the treatments 80% sucrose + ascorbic acid and 80% sucrose + pectin were the ones that received high means and good AI (%) in practically all attributes. It is probable that the reason for this choice was the color enhancement of the dehydrated fruit caused by the use of ascorbic acid and pectin + sucrose,[26,28] in addition to the good combination of taste, aroma and texture. In contrast, the treatment 60% sucrose + citric acid did not reach 70% AI in any of the attributes. This may be justified by the fact that the citric acid acidifies the strawberry flavor.[29]

A study conducted by Basílio et al.,[7] to evaluate the acceptance of yogurt with the addition of dehydrated strawberries with 28 judges, found that 64% of the evaluators liked the taste of the product, 68% the aroma and 54% would buy the product, demonstrating the potential of dehydrated strawberries. In the study carried out by Balke et al.,[30] with peaches obtained by different drying methods, there was a good general acceptance for the treatments performed with osmotic dehydration, oven and lyophilisation.

Table 2 shows the values found for the content of soluble solids, titratable acidity and pH of the strawberries.

Table 2. Soluble solids content (SS) (°Brix), titratable acidity (TA) (mg citric acid 100 g^{-1}), SS/TA ratio and pH (mean±standard deviation) of dehydrated strawberries under different treatments[1]. Guarapuava-PR, 2016.

Treatment	Soluble solids (°Brix)	Titratable acidity (g 100 g^{-1})	SS/TA Ratio	pH
Control	9.1 ± 0.1 c	3.5 ± 0.05 d	2.59 ± 0.05 b	3.72 ± 0.03 a
80% + citric acid	10.7 ± 0.1 b	4.2 ± 0.09 c	2.52 ± 0.03 bc	3.45 ± 0.02 b
80% + ascorbic acid	10.4 ± 0.4 b	4.7 ± 0.02 a	2.22 ± 0.09 d	3.35 ± 0.01 d
80% + pectin	12.4 ± 0.3 a	4.2 ± 0.02 c	2.94 ± 0.08 a	3.39 ± 0.01 cd
60% + citric acid	10.3 ± 0.1 b	4.4 ± 0.04 b	2.33 ± 0.01 cd	3.24 ± 0.01 e
60% + ascorbic acid	9.3 ± 0.4 c	4.2 ± 0.04 c	2.20 ± 0.09 d	3.37 ± 0.01 d
60% + pectin	10.2 ± 0.4 b	4.6 ± 0.04 a	2.22 0.07 d	3.42 ± 0.01 bc

[1] Different letters in the column indicate significant difference by the Tukey's test ($p<0.05$); 80% = 80% sucrose; 60% = 60% sucrose.

Concerning the soluble solids content, it was possible to observe that the greatest solids gain occurred for the treatment with 80% sucrose + pectin, which differed from the others (12.4 °Brix). This may have been due to the amount of pectin absorbed by the fruit, which, because it was soluble, was accounted for in the analysis of soluble solids. Differently from the present study, Campo[26] demonstrated that there was a greater difference between the concentrations of 60 and 80% sucrose in relation to the soluble solids content, with contents of 8.06 °Brix and 10.84 °Brix, respectively.

The most abundant components and which are part of soluble solids (xylitol, sorbitol and xylose) are related to strawberry sweetness.[31] According to Kader,[32] the *in natura* strawberry has a total soluble solids content between 4.1 and 11.9 °Brix, depending on the cultivar and on pre-harvest factors. In the present study, the strawberries presented initial °Brix (*in natura*) around 5.0, and in addition to the concentration of sugars present in the fruit after dehydration, sugar was added as sucrose solution, which increased even more the soluble solids content.

Titratable acidity is an indicator of the amount of organic acids present in the fruit, being important for the sensory characteristics, since it adds flavor.[33] In the present study, the highest titratable acidity values were found for treatments with 80% sucrose + ascorbic acid and 60 % sucrose + pectin, with 4.7 and 4.6 g 100 g^{-1}, respectively. The lowest value was observed for the control treatment, with 3.5 g 100 g^{-1}. The treatments with 80% sucrose + citric acid, 80% sucrose + pectin and 60% sucrose + ascorbic acid did not differ from each other.

The soluble solids and titratable acidity ratio (SS/TA) is of paramount importance for sensory analysis, since it demonstrates the balance between sugar and acidity, determining the flavor of the fruit.[34] The highest value found for the SS/TA ratio was for the treatment with 80% sucrose + pectin (2.94), one of the most sensorially well-accepted. However, it is possible to observe that this factor (SS/TA ratio) is not the only determinant of the sensory acceptance of the tasters, since the treatment 80% sucrose + ascorbic acid, even with low values for the SS/TA ratio (2.22), was well accepted.

The pH is one of the factors that exerts a greater selective effect on the development of microflora in foods.[35] The highest pH value found was in the control treatment (3.72), and the lowest was in the treatment with 60% sucrose + ascorbic acid (3.37). The treatments with 80% sucrose + ascorbic acid (3.35) and 60% sucrose + ascorbic acid (3.37) obtained similar values and did not differ from the treatment with 80% sucrose + pectin. In the study conducted by Guimarães,[33] a pH of 3.81 was observed for dehydrated strawberry, a value similar to those found in the present study.

Table 3 shows the contents of total phenolic compounds, anthocyanins and ascorbic acid of dehydrated strawberries with different treatments.

Table 3. Content of phenolic compounds (mg gallic acid 100 g^{-1}), content of anthocyanins (mg cyanidin 3-glycoside 100 g^{-1}) and content of ascorbic acid (mg ascorbic acid 100 g^{-1}) (mean±standard deviation) of strawberries dehydrated with different treatments[1]. Guarapuava-PR, 2016.

Treatment	Phenolics (mg 100 g^{-1})	Anthocyanins (mg 100 g-1)	Ascorbic acid (mg 100 g-1)
Control	105.8 ± 6.2 d	11.4 ± 1.3 e	33.8 ± 2.6 e
80% + citric acid	221.7 ± 5.4 a	56.4 ± 3.9 b	88.4 ± 1.5 a
80% + ascorbic acid	221.9 ± 3.6 a	50.7 ± 3.2 c	79.1 ± 0.9 b
80% + pectin	220.6 ± 3.2 a	68.1 ± 3.9 a	81.5 ± 2.6 b
60% + citric acid	193.2 ± 7.8 c	25.5 ± 1.6 d	55.3 ± 3.5 c
60% + ascorbic acid	215.6 ± 4.9 a	51.0 ± 1.9 c	60.1 ± 0.6 c
60% + pectin	202.5 ± 8.9 b	60.6 ± 3.5 b	44.7 ± 0.7 d

[1] Different letters in the column indicate significant difference by the Tukey's test ($p<0.05$); 80% = 80% sucrose; 60% = 60% sucrose. Results on dry basis.

One of the main characteristics of osmotic dehydration is the penetration of solutes in the sample, and it is possible to modify its formulation to a certain extent by adding water-activity-reducing agents, ingredients or additives such as antioxidants and other preservatives to the food, thus preserving bioactive compounds of nutritional or sensory interest.[36,37]

In general, osmotic pretreatment followed by dehydration preserved and concentrated the bioactive compounds in the strawberry, probably because the dehydration caused few changes in the food, some of them expected, such as water loss and nutrient concentration per unit mass.[38] This occurred because in this process there is the difference in concentration between the osmotic agent and the strawberry, immersed in solution, of sucrose, plus the preservative agents, with water activity lower than the food.[26]

In addition, the low drying temperature used (60 °C) may have contributed to the maintenance of these compounds, since conventional drying combined with the osmotic pretreatment may obtain greater retention of the product's natural color and preservation of volatile components.[39]

El-Aquar & Murr[40] observed that the use of citric acid in 70 °Brix sucrose solution, as an osmotic pretreatment in papayas, promoted lower solids gain and higher water loss, thus preserving bioactive compounds such as vitamin C and carotenoids, since these additives prevent the degradation by oxidation of the compounds present in fruits. On the other hand, sucrose seems to govern the process of mass transfer, since it is in greater quantity in relation to the other added ingredients, i.e., when the concentration of the solution increases, water loss and solids gain occur.

The content of phenolic compounds was higher for the treatments 80% sucrose + citric acid, 80% sucrose + ascorbic acid, 80% sucrose + pectin and 60% sucrose + ascorbic acid, which did not differ from each other. The control treatment had the lowest content of phenolic compounds. This demonstrates that high sugar contents and the presence of acid (ascorbic or citric) probably have a protective effect for total phenolic compounds in dehydration.

Mendes et al.[41] found satisfactory results when submitting oranges to the osmotic dehydration process with 70% sucrose solution and addition of citric acid and ascorbic acid, followed by conventional drying at 65 °C. In their study, oranges receiving the osmotic pretreatment presented better results in terms of contents of phenolic compounds (4.0 mg 100 g^{-1}) in relation to dehydrated oranges without treatment (1.7 mg 100 g^{-1}). Therefore, the osmotic pretreatment was effective in the retention of the phenolic compounds present in the orange, corroborating the results of this study.

The anthocyanin content was more concentrated in the treatments with addition of pectin + 80% sucrose, pectin + 60% sucrose, citric acid + 80% sucrose, ascorbic acid + 60% sucrose and ascorbic acid + 80% sucrose. The control treatment and the treatment of citric acid + 60% sucrose, however, presented lower contents of anthocyanins. Shigematsu et al.[42] suggest that the addition of pectin increases the resistance of fruit tissue, reducing sucrose transfer, which acts as a preservative. Hence, the pectin coating becomes impregnated, making the fruit more concentrated, thus preserving the anthocyanins and maintaining its color.

During the thermal process, degradation of anthocyanins may occur, as observed in the control treatment and in the treatment with citric acid + 60% sucrose. In the present study, however, values that demonstrate their conservation have been observed in some treatments, which, as in the case of total phenolics, may have been preserved by the high concentration of sucrose in combination with the added agents.

Ascorbic acid content was more concentrated in treatments with addition of acids and pectin in relation to the control treatment, and the treatment 80% sucrose + citric acid presented the highest content (88.4 mg 100 g^{-1}), followed by the other two treatments with 80% sucrose + ascorbic acid or pectin, which did not differ from each other. Guimarães et al.[33] observed that dehydration in strawberries without osmotic pretreatment reduced ascorbic acid contents to 35.69 mg 100 g^{-1}, results similar to the contents found for the control treatment of this study. In the studies conducted by Egea & Lobato[43] and Mendes et al.[41] in dehydrated apples and oranges, vitamin C losses decreased with the osmotic process as a pretreatment for convective drying, corroborating the study.

It is possible to observe that the treatments with citric acid, pectin and ascorbic acid, in addition to sucrose, obtained a higher concentration of bioactive compounds than the control sample. According to Falade & Igbeka,[44] this is due to the osmotic treatment, which is a combination of dehydration and of impregnation which minimizes negative modifications of fresh food components. In other words, it is a process of immersion of fruits and vegetables in salt, sugar or combined solution to reduce the water content while increasing the soluble solids content.[26] According to Alakali et al.,[45] the most common dehydrating agent for fruits is sucrose, which is also considered a great osmotic agent, as it prevents enzymatic browning and loss of aromas. This prevention is due to the presence of a layer of the disaccharide, formed on the surface of the dehydrated product, which constitutes an obstacle to the contact with oxygen, which minimizes or prevents enzymatic browning, besides having a positive influence on the maintenance of color and flavoring substances of the food.

In this sense, the addition of sucrose may be involved in two mechanisms that may have influenced the retention of phenolic compounds and anthocyanins. The first one involves the enzymatic browning reaction; the enzymes responsible for browning, especially peroxidase and polyphenoloxidase, in contact with oxygen, cause the oxidation of phenolic compounds. As this process is minimized by the formation of the abovementioned obstacle, the degradation of the phenolic compounds can be avoided.

A second mechanism for the retention of phenolic compounds when using sucrose as an osmotic pretreatment may be the protective effect given by the complexation of phenolic compounds with sugar molecules, forming larger complexes that could not cross the cell membrane.[46,47] This protective effect of the impregnation of sugars has been verified in previous studies for strawberry and kiwifruit in compounds such as ascorbic acid, chlorophyll and anthocyanins.[48]

Besides sucrose, the addition of compounds such as ascorbic acid, citric acid and pectin reduces the deterioration of fruits while maintaining their quality. These compounds act as antioxidants, enhancing fruit shelf life by reducing browning reactions, pigment discoloration, sensory and nutritional losses.[26] Possibly, the combined action of substances added to the pretreatment aided in the preservation of the compounds of nutritional interest, which may be concluded especially when comparing the control treatment with the others.

According to Calegaro et al.,[49] the maintenance of the color of strawberries during storage is a desired quality attribute, since the darkening of the fruits compromises their visual aspect and, thus, their acceptance by the consumer. The results obtained for the coloring of the dehydrated strawberries are expressed in table 4.

Table 4. Luminosity (L) and hue angle (°hue) (mean±standard deviation) of dehydrated strawberries with different treatments[1]. Guarapuava-PR, 2016.

Treatment	Luminosity (L)	°Hue
Control	31.3 ± 0.7 cd	34.6 ± 3.6 ab
80% + citric acid	31.4 ± 1.1 cd	26.9 ± 4.3 bc
80% + ascorbic acid	32.6 ± 0.8 bc	28.3 ± 2.9 abc
80% + pectin	34.2 ± 0.8 ab	20.3 ± 4.2 c
60% + citric acid	30.4 ± 0.2 d	37.8 ± 2.9 a
60% + ascorbic acid	34.4 ± 0.4 ab	30.7 ± 3.2 ab
60% + pectin	35.4 ± 0.2 a	34.0 ± 2.1 ab

[1] Different letters in the column indicate significant difference by the Tukey's test ($p<0.05$); 80% = 80% sucrose; 60% = 60% sucrose.

Regarding color, there was a tendency for a lower darkening of the samples (increase in L* value) after dehydration with 80 and 60% sucrose + pectin and 60% sucrose + ascorbic acid, since the values of L* varied from 0 (totally dark) to 100 (clear). The color changes (L-value) may be explained by the absorption of sugars during the osmosis and its concentration during drying, as well as by the effect of temperature, which favors browning processes, avoided in part by the addition of sugar and of preservative ingredients. Reis et al.[50] verified that the color of red fruits became reddish brown with dehydration by different treatments, with a mean of L similar to those found in this study. The evaluation of the color is an important parameter, because it is through it that one may evaluate if the fruit really reached or not ideal conditions of commercialization. According to El-Aouar et al.,[51] when combining conventional drying to the osmotic process with addition of preservatives, there is greater retention of the product's natural color, preservation of volatile components and minimization of shrinkage, as well as reduction of energy consumption during the drying stage.

The Hue angle indicates the shade of a product (0° red, 90° yellow, 180° green, 270° blue).[52] In the present study, the samples were closer to 0°, indicating a red color. The treatment with 80% sucrose + pectin was the closest to 0°, having the most intense red color, however, it did not differ from the treatments 80% sucrose + ascorbic acid and 80% sucrose + citric acid. The treatments 80% sucrose + citric acid, 80% sucrose + ascorbic acid, 60% sucrose + ascorbic acid, 60% sucrose + pectin and the control treatment did not differ from each other.

Mendes et al.[41] pointed out in their studies that dehydrated fruits, such as oranges, present higher saturation indexes during the process, i.e., stronger and more intense colors due to the increase in solids concentration.

Conclusion

The results indicated that the osmotic treatment with 80% sucrose and the addition of ascorbic acid or pectin followed by dehydration was well accepted by the tasters. The addition of these ingredients improved the consumer's acceptance of the color, aroma and texture of the product when compared to dehydrated strawberries without pretreatment (control). The highest soluble solids content was verified for the treatment 80% sucrose + pectin, as well as the higher SS/TA ratio, which may have influenced the preference of the tasters for this treatment, however, it is not a conditioning factor for the preference, since the treatment 80% sucrose + ascorbic acid showed good acceptability and lower SS/TA ratio.

Regarding the content of phenolic compounds, anthocyanins and ascorbic acid, treatments with sucrose addition and preservative ingredients, such as ascorbic acid, citric acid and pectin, presented higher contents in relation to the control treatment, especially those with 80% sucrose.

The treatments with 80% sucrose + pectin or ascorbic acid or citric acid were the ones that presented a more intense red color in relation to the other treatments.

In this sense, the elaboration of the dehydrated strawberry with pretreatment of 80% sucrose + ascorbic acid or pectin is a good alternative for strawberry preservation, and it may be used by small farmers, besides preserving compounds of nutritional interest and color.

Acknowledgments

The authors would like to thank Bruna Tais Noronha, Kelly Cristiane Michalichen and Priscila Lumi Ishii for their assistance and collaboration during research and experimental work.

Contributors

Alves V, Schwarz K and Luz FR participated in the conception and design of the study, from the analysis and interpretation of the data and elaboration of the article to the final version. Resende JTV supported the study, providing the structure and equipment to perform the experimental part. Vieira RLD and Bennemann GD participated in the critical content review.

Conflict of interest: The authors declare that there are no conflicts of interest.

References

1. Instituto de Tecnologia dos Alimentos. Conservação do morango. Campinas: ITAL; 1978. 212 p.
2. Han C, Lederer C, McDaniel M, Zhao Y. Sensory evaluation of fresh strawberrie (Fragaria ananassa) coated with chitosan-based edible coatings. Journal of Food Science. 2005; 70(3):S172-S178.
3. Oszmianski J, Wojdylo AA. Comparative study of phenolic content and antioxidant activity of strawberry puree, clear, and cloudy juices. European Food Research and Technology. 2009; 228(4):623-631.
4. Ariza MT, Reboredo-Rodríguez P, Mazzoni L, Forbes-Hernández TY, Giampiere F, Afrin S, et al. Strawberry achenes are an important source of bioactive compounds for human health. Int J Mol Sci. 2016; 17(7):1103.
5. Giménez G, Andriolo J, Godoi R. Cultivo sem solo do morangueiro. Ciência Rural. 2008; 38(1):273-279.
6. Lima F. Pesquisa pretende desenvolver morango brasileiro. 2015. Agron – Agronegócio Online [Internet]. 16 ago. 2018. [acesso em: 10 dez. 2017]. Disponível em: https://www.agron.com.br/publicacoes/noticias/ciencia-e-tecnologia/2015/08/22/045421/pesquisa-pretende-desenvolver-morango-brasileiro.html

7. Basílio MP, Charbel ALT, Ferreira AG. Avaliação da secagem de morangos em estufa e em secador híbrido solar-elétrico. Revista Acadêmica Conecta FASF [Internet]. 2016; 1(1). Disponível em: http://revista.fasf.edu.br/index.php/conecta/article/view/16/pdf

8. Dias MC. Desperdício de alimentos. Correio Braziliense [Internet]. 31 ago. 2003. [acesso em: 10 dez. 2017]. Disponível em: http://www.consciencia.net/2003/09/06/comida.html

9. Duarte Filho JD, Antunes LEC, Pádua JG. Cultivares. Informe Agropecuário. 2007; 28(236):20-23.

10. Del-Valle V, Muñoz PH, Guarda A, Galotto MJ. Development of a cactusmucilage edible coating (Opuntia ficus indica) and its application to extend strawberry (Fragaria ananassa) shelf-life. Food Chemistry 2005; 91(4): 751-756.

11. Cia P, Bron IU, Valentini SRT, Pio R, Chagas EA. Atmosfera modificada e refrigeração para conservação pós-colheita da amora-preta. Bioscience Journal. 2007; 23(3): 11-16.

12. Vargas M, Albors A, Chiralt A, González-Martínez C. Quality of coldstored strawberries as affected by chitosan-oliec acid edible coatings. Postharvest Biology and Technology. 2006; 41:164-171.

13. Quinato EE, Degáspari CH, Vilela RM. Aspectos nutricionais e funcionais do morango. Visão Acadêmica [Internet]. 2007; 8(1). Disponível em: https://revistas.ufpr.br/academica/article/view/11660

14. Celestino SMC. Princípios de secagem de alimentos. Planaltina, DF: Embrapa Cerrados; 2010.

15. Souza Neto MA, Maia GA, Lima JR, Figueiredo RW, Souza Filho MSM, Lima AS. Desidratação osmótica de manga seguida de secagem convencional: avaliação das variáveis de processo. Ciência e Agrotecnologia. 2005; 29(5):1021-1028.

16. Kluge RA, Nachtigal JC, Fachinello JC, Bilhalva AB. Fisiologia e manejo pós-colheita de frutas de clima temperado. 2. ed. Campinas: Livraria Rural; 2002. 214 p.

17. Costa ARS, Ferreira SR. Sistema de secado solar para frutos tropicais. Informacíon Tecnológica. 2007; 18(5):49-58.

18. Pesquisa Industrial [Internet]. Rio de Janeiro: IBGE. v. 30, n. 2. 2011. [acesso em: 9 dez. 2017]. Disponível em: http://biblioteca.ibge.gov.br/visualizacao/periodicos/1719/pia_2011_v30_n2_produto.pdf

19. Brasil. Ministério da Saúde. Secretaria da Vigilância Sanitária. Resolução CNNPA n.12, 23 de julho de 1978. Normas Técnicas Especiais. Diário Oficial da União 24 jul. 1978.

20. Dutcosky SD. Análise sensorial de alimentos. 3. ed. Curitiba: Champagnat; 2011.

21. Teixeira E, Meinert E, Barbetta PA. Análise sensorial de alimentos. Florianópolis: UFSC; 1987. 180 p.

22. Association of Official Analitical Chemists. Official methods of analisys of AOAC International. Gaithersburg, MD: AOAC; 1984.

23. Woisky RG, Salatino A. Analysis of propolis: some parameters and procedures for chemical quality control. Journal of Apicultural Research. 1998; 37(2):99-105.

24. Giusti MM, Wrolstad RE. Anthocyanins: characterization and measurement with uv-visible spectroscopy. In: Wrolstad RE. Current protocols in food analytical chemistry. New York: John Wiley and Sons; 2001. p. 121-130.

25. Benassi MT, Antunes AJ. A comparison of methaphosphoric and oxalic acids as extractant solutions for the determination of vitamin C in selected vegetables. Brazilian Archives of Biology and Technology. 1988; 31:507-513.

26. Campo C. Desidratação osmótica de morangos cv. Aromas [Trabalho de Conclusão de Curso]. [Bento Gonçalves]: Instituto Federal de Educação, Ciência e Tecnologia; 2012.

27. Nigihan M, Karaashan M. Anthocyanin profile of strawberry fruit as affected by extraction conditions. International Journal of Food Properties. 2017; 20:S2313-S2322.

28. Fernandes TN. Relação entre a adição de sacarose e pectina, comportamentos reológicos e dinâmicos do congelamento e descongelamento de polpas de morango e abacaxi [dissertação]. [Lavras]: Universidade Federal de Lavras; 2008.

29. Aplicações do ácido cítrico na indústria de alimentos. Food Ingredients Brasil [Internet]. 2014. Disponível em: http://www.revista-fi.com/materias/402.pdf.br

30. Balke ME, Oliveira HT, Steffens C, Valduga E, Soares ABJ, Steffens J, Soares MBA. Avaliação Sensorial de pêssegos obtidos por diferentes métodos de secagem. Congresso Brasileiro de Engenharia Química. Anais do Congresso Brasileiro de Engenharia Química; 2014; Florianópolis. Florianópolis: COBEQ; 2014. 8 p.

31. Azevedo SMC. Estudos de taxa de respiração e de fatores de qualidade na conservação de morango fresco [dissertação]. [Lisboa]: Universidade Aberta; 2007.

32. Kader AA. Quality and its maintenance in relation to postharvest physiology of strawberry. Oregon: Timber Press; 1991. p. 145-152.

33. Guimarães AG, Oliveira CM, Vieira G, Pinto NAVD. Qualidade físicas e químicas de morango passa em diferentes embalagens. Engenharia na Agricultura. 2014; 22(4):306-316.

34. Thé PMP, Carvalho VD, Abreu CMF, Nunes RF, Pinto NAVD. Efeito da temperatura de armazenamento e do estádio de maturação sobre a composição química de abacaxi cv. Smooth cayene L. Ciência e Agrotecnologia. 2001; 25(2): 356-363.

35. Franco BDGM, Landgraf M. Microbiologia de alimentos. São Paulo: Atheneu; 2003.182 p.

36. Torreggiani D, Bertolo G. Osmotic pre-treatments in fruit processing: chemical, physical and structural effects. Journal of Food Engineering. 2001; 49:247-253.

37. Pereira LM. Acondicionamento de goiabas minimamente processadas por desidratação osmótica em embalagens sob atmosfera modificada [dissertação]. [Campinas]: Faculdade de Engenharia de Alimentos, Universidade Estadual de Campinas; 2002.

38. Colpo LP. Avaliação da capacidade antioxidante e conteúdo de compostos fenólicos de frutas vermelhas submetidas a processamentos por calor (micro-ondas, sous vide, fervura e desidratação) [dissertação]. [São Leopoldo]: Faculdade de Nutrição, Universidade do Vale do Rio dos Sinos; 2015.

39. El-Aquar AA. Avaliação do processo combinado de desidratação osmótica e secagem na qualidade de cubos de mamão formosa (Carica papaya L.) [dissertação]. [Campinas]: UNICAMP; 2001.

40. El-Aquar ÂA, Murr FEX. Estudo e modelagem da cinética de desidratação osmótica do mamão formosa (Carica papaya L.). Ciênc. Tecnol Aliment. 2003; 23(1):69-75.

41. Mendes GRL, de Freitas CH, Scaglioni PT, Schmidt CG, Furlong EB. Condições para desidratação osmótica de laranjas e as propriedades funcionais do produto. Revista Brasileira de Engenharia Agrícola e Ambiental. 2013; 17(11):1210-1216.

42. Shigematsu E, Eik NM, Kimura M, Mauro MA. Influência de pré-tratamentos sobre a desidratação osmótica de carambolas. Ciênc. Tecnol Aliment. 2005; 25(3):536-545.

43. Egea MB, Lobato LP. A desidratação osmótica como pré-tratamento para frutas e hortaliças. Rev Inst Adolfo Lutz. 2014; 73(4): 316-324.

44. Falade KO, Igbeka JC. Osmotic dehydration of tropical fruits and vegetables. Food Reviews International. 2007; 23: 373 - 405.

45. Alakali JS, Ariahu CC, Nkpa NN. Kinetics of Osmotic Dehydration of Mango. Journal of Food Processing and Preservation. 2006; 30(5): 597-607.

46. Heng K, Guilbert S, Cuq JL. Osmotic dehydration of papaya: influence of process variables on the product quality. Sciences des Aliments. 1990; 10: 831-848.

47. Taku MA, Yukiko S, Masaru W, Kiyohiko T, Toshiyuki N, Hideo H, Kunio A. Dehydration of D-glucose in high temperature water at pressures up to 80 MPa. The Journal of Supercritical Fluids. 2007; 40(3):381-388.

48. Bobbio FO, Bobbio PA. Introdução à química de alimentos. 3. ed. São Paulo: Livraria Varela; 2003.

49. Calegaro JM, Pezzi E, Bender RJ. Utilização de atmosfera modificada na conservação de morangos em pós-colheita. Pesquisa Agropecuária Brasileira. 2002; 37(8):1049-1055.

50. Reis KC, Siqueira HH, Alves AP, Silva DJ, Lima LC. O. Efeito de diferentes sanificantes sobre qualidade de morango cv. Oso Grande. Ciência e Agrotecnologia. 2008; 32(1):196-2002.

51. El-Aouar AA, Azoubel PM, Barbosa Junior JL, Murr FEX. Influence of the osmotic agent on the osmotic dehydration of papaya (Carica papaya L.). Journal of Food Engineering. 2006; 75:267-274.

52. Garcia EL, Carmo EL, Pádua JG, Leonel M. Potencialidade de processamento industrial de cultivares de batatas. Ciência Rural. 2015; 45(10):1742-1747.

Received: December 19, 2017
Reviewed: July 16, 2018
Accepted: August 08, 2018