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Effect of storage on the physicochemical properties, total phenolic, anthocyanin, and antioxidant capacity of strawberry jam

Taha M. Rababah [1*], Muhammad H. Al-u'datt [1], Majdi A. Al-Mahasneh [2], Hao Feng [3] , Abdulaziz M. Alothman [4], Ali Almajwal [4], Wade Yang [5], Isra Kilani [1], Mohammad N. Alhamad [1], Khalil Ereifej [1] and Mohammad Abu-Darwish [6]

*[1]Faculty of Agriculture. [2]Faculty of Engineering, Jordan University of Science and Technology, P.O. Box 3030, Irbid 22110, Jordan. [3]Department of Food Science and Human Nutrition, University of Illinois at Urbana-Champaign, 1304 West Pennsylvania Avenue, Urbana, IL 61801. [4]Department of Community Health Sciences, College of Applied Medical Sciences, King Saud University, P.O. Box 10219 Riyadh 11433, Saudi Arabia. [5]Department of Food Science and Human Nutrition, University of Florida, P.O. Box 110370, Gainesville, FL 32611-0370. [6]ASh-Shoubak University College, Al-Balqa' Applied University, Al-Salt 19117, Jordan. *e-mail:trababah@just.edu.jo, muhammad.aludatt@mail.mcgill.ca*

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Abstract

The purpose of this study was to evaluate the effect of jam processing with strawberries on the total phenolics, antioxidant activity, anthocyanins and physicochemical properties (pH, soluble solids, firmness and color storage) during a 15-day sotage at 25, 35, 45 and 55°C. The results showed that fresh strawberries had the highest concentration of total phenolics, antioxidant compounds and anthocyanins (1693.55 mg GAE/100 g, 84.91%, and 18.59 mg cya-3-glu, respectively). The antioxidant activity and anthocyanins of jam decreased quickly when storage at temperature of 35 to 55°C. Moreover, a fast in firmness of jam was observed when stored at 55°C. The lightness, yellowness and ΔE of strawberry jam increased, whereas the redness decreased during the storage. The yellowness and chroma of the jam increased with temperature from 35 to 55°C, and the ΔE increased only when stored at 55°C. In spite of the significant reduction in these nutraceutical compounds, jam processing retained good amounts of them during storage at different temperatures.

Key words: Strawberry, jams, antioxidant, physiochemical properties.

Introduction

Fruit jams are very popular in Jordan. There is a considerable demand for fresh fruits as well as their products. Since many types of fruits are seasonal and their shelf lives are limited, they must be processed to keep the quality [1]. Jam processing is one of the popular methods to preserve perishable fruits [2]. It is known that quality parameters of fruit jams, such as color, acidity, soluble solids, texture and nutraceutical content, can be affected during processing and storage [3, 4]. Amakura *et al.* [5] reported that the total phenolics, antioxidant activity and anthocyanin compounds of processed fruits can be reduced during storage. Patras *et al.*[6] found some degradation of bioactive compounds including ascorbic acid, anthocyanins, total phenolics, colour and antioxidant activity in strawberry during storage. Anthocyanins and their color stability depend on various factors such as pH-value, presence of oxygen, enzyme activity, temperature, sugar and ascorbic acid content [7]. Jam structure is determined by the equilibrium between the pectin, sugar and acid contents present in the fruit [8], which are fundamental components of soluble solid contents [9]. Kopjar *et al.* [10] showed that pectin and storage time affected the color, antioxidant activity and texture of strawberry jams.

In the Middle East strawberry is considered as one of the main fruits that are often processed into jams. Literature that focuses on the behavior of total phenolics, antioxidant activity and anthocyanins of strawberry jams during storage is rather limited; furthermore, it is of interest to increase our understanding of the effect of jam processing and storage on the stability of nutraceutical compounds in strawberry. The objective of the present study was to evaluate the total phenolics, antioxidant activity and anthocyanins and physiochemical properties including pH, soluble solids, firmness and color including total color differences (ΔE) and chroma values of strawberry jam at different temperatures during storage.

Materials and Methods

Materials: Strawberry (*Fragaria* × *ananassa*) was purchased from a local market in Jordan. Sodium carbonate Na_2CO_3 was purchased from NTL (U.K), methanol and Folin-Ciolateu reagents and gallic acid were purchased from Sigma Aldrich agent (Amman-Jordan), 2,2-diphenyl-1-picrylhydrazyl (DPPH) and HCl and all other chemicals and standards were purchased from local agents (Amman, Jordan). Citric acid, high methoxy (HM) pectin (150-SAG type B rapid set, USA) and glass jars (100 ml) were obtained from Asia Food Industries (Amman Jordan). All solutions were prepared using distilled water.

Jam processing: Jam processing was conducted following the

procedure described by Downing [11]. Fruits were sorted, washed, and ground using a mixer at 1400 rpm for 60 s. Jam formulation was 40% fruit, 51% sugar, 8.6% water and 0.4% high methoxy pectin. Ground fruits were heated in a double-jacketed steam kettle at 80°C for 10 min to inactivate enzymes. After that, pectin was added under manual agitation and the mixture was heated for 2 min to allow proper pectin hydration. Acidity was checked and adjusted if needed by addition of 0.3% citric acid solution to a pH value from 3.0 to 3.2. Sugar was added, and the mixture was boiled to a final concentration around soluble solids value of 65% (approximately 104 to 105°C final boiling point). The jam was hot-packed at 85°C in 100 ml glass jars, immediately sealed with metal cover and inverted for 5 min to sterilize the glass containers. The jars were returned to normal position for holding at 50°C. Samples were stored at 25°C in the Food Research Laboratory, Faculty of Agriculture, Jordan University of Science and Technology, until analysis.

Extract preparation: The fruit and jam extracts were prepared as described by Rababah *et al*. with some modification [12]. Two g of each sample was weighed out and extracted with 50 ml of methanol. The extraction was carried out under stirring for 60 min at 60°C. Each fruit and jam extract was filtered using Whatman No. 3 filter paper, filled in a 50 ml volumetric flask and allowed to set in the dark until analysis.

Determination of total phenolics: Total phenolic content in extracts was determined according to the Folin-Ciocalteu procedure [13] with slight modifications as follows: 100 µl of the fruit and fruit jam extracts (triplicate) were transferred into a test tube and mixed with 0.4 ml of 10% Folin-Ciocalteu reagent. After 3 min reaction 0.8 ml of 10% Na_2CO_3 was added. The tubes were allowed to stand for 1 hour at ambient temperature, and the absorption was measured at 725 nm using a spectrophotometer (CELL, model CE 1020) against a blank, which contained 100 µl of methanol in place of sample. Gallic acid was used as calibration standard, and the results were calculated as gallic acid equivalent (GAE) (mg/100 g dry weight basis).

Determination radical DPPH-scavenging activity: DPPH radical scavenging effect was determined according to the method of Mattaus [14]. Approximately, 2 g in triplicate of each sample was extracted under stirring with 50 ml methanol for 60 min at 60°C and 500 µl of methanol extracts allowed to react with 0.2 ml of DPPH solution. The mixture was brought to a total volume of 4.0 ml with the extracting solvent. The mixture was mixed thoroughly and allowed to stand in the dark for 30 min. Absorbance (A) was determined at 515 nm, against the blank. The radical scavenging activity was expressed as % of inhibition according to the following formula:

Inhibition (%) = [(A of control - A of sample)/A of control] × 100.

Determination of total anthocyanins

Preparation of fruit and jam extract: The fruit and jam extract were prepared by an established procedure as described by Rabino and Mancinell [15]. About 2 g (triplicate) of each material was weighed out and extracted with 50 ml of acidified (1% HCl v/v) methanol. Extraction was carried out under stirring for 60 min at 60°C. Each extract was filtered out using Whatman No. 3 filter paper, filled accordingly in a 50 ml volumetric flask, and allowed to set in the dark until it was used.

Determination of total anthocyanins: Total anthocyanin content in the extracts was determined according to the procedure described by Rabino and Mancinell [15] with some modifications. After extraction of anthocyanins with acidified methanol, the absorbance of the extracts was measured using a spectrophotometer (CELL, model CE 1020, England) at 530 and 657 nm. Using formula A = (A530- 0.25 A657) to compensate the contribution of chlorophyll and its degraded products to the absorption at 530 nm. The anthocyanin content was expressed as mg of Cya-3-glucoside equivalent per 100 g of dry sample weight.

Physicochemical measurements

Acidity: Citric acid was added to jams only to get a final pH of 3.0-3.3. The pH of fruits and fruit jams was measured at room temperature of 25°C by using a pH meter (pH 510, EVTECH instrument, Malaysia). The pH meter was calibrated with pH buffers 4 and 7. The glass electrode was put directly into the fruits and fruit jams and the resulting pH values were recorded.

Soluble solids (SS): The total soluble solids were measured at room temperature of 25°C by a digital refractometer (Atago HTT, Illuminator, Japan) with scale (0-95%). For fruits, only, TSS was determined before preservation in 20% of sugar. Results were expressed in percentage.

Firmness: The firmness measurements were performed directly in the fruit jams at room temperature of 25°C with a texture analyzer (model WDW-E2, Jinan testing equipment IE Corporation, China). The firmness was determined with the test mode compression, to this purpose a flat cylindrical stainless steel probe with a diameter of 13.85 mm was used. Compression test started when the probe got in contact with fruit jam surface. The probe speed during compression was 10 mm/s. After compression, the probe was moved upward and the firmness value (N) was recorded as the value of peak force in triplicates [16].

***Color measurement*:** Color was measured by a colorimeter (12MM Aperture U 59730 Inc., Pittsford, New York, USA) and recorded in the *L*, a*, b** color system. This color system consists of a luminance or Lightness component (*L**) and two chromatic components: the *a** component for green ("a) to red (+a) and the *b** component from blue (-b) to yellow (+b) colors. The colorimeter was calibrated throughout the study by using a standard white ceramic reference (Commission International-ale de Ι`Eclairage *L** = 97.91, *a** = - 0.68, and *b** = +2.45). Three samples were used for each fruit and its jam and the measurements were averaged. In addition, total color difference (ΔE) and chroma were calculated using the following equations, $\Delta E = [(\Delta a)^2 + (\Delta b)^2 + (\Delta L)^2]^{½}$, chroma = $[(a)^2 + (b)^2]^{½}$.

Statistical analysis: Data were analyzed using the general linear model (GLM) procedure with JMP statistical package (JMP Institute Inc., Cary, NC). Means were separated by LSD analysis at a least significant difference at p = 0.05. The correlation

coefficient (R^2) among the total phenolics, antioxidant activity and anthocyanins were also investigated.

Results and Discussions

Total phenolics, antioxidant activity and anthocyanins: The results of total phenolics, antioxidant activity, and anthocyanins (Table 1) showed that strawberry fruits had significantly ($P \leq 0.05$) the highest amount of total phenolics (1693.55 mg GAE/100 g) followed by strawberry jam after processing (848.86 mg GAE/100 g) and strawberry jam stored for 15 days at 25°C (408.62 mg GAE/100 g), and the other storage temperatures, respectively. The reduction of total phenolics during jam cooking might be due to disruption of the cell structure during strawberry fruits processing [6]. The antioxidant activity of the strawberry fruit as showed by inhibition percent was the highest (84.91%) among all the samples, followed by strawberry jam after processing (59.38%), and jams stored for 15 days at 25°C (55.13%), 35°C (32.05%), 45°C (29.82%), and 55°C (16.95%) (Table 1). The results of antioxidant activity agreed with Wicklund et al. who reported that there was a reduction of antioxidant activity and anthocyanins in strawberry jams stored for three months at 4 and 20°C [4]. Wicklund also demonstrated that the temperature was the most important factor which caused reduction of antioxidant activity and concentration of anthocyanins. The concentration of anthocyanins (Table 1) in the strawberry fruit was the highest (18.59 mg cya-3-glu/100 g), followed by strawberry jam after processing (7.10 mg cya-3-glu/100g), strawberry jams stored for 15 days at 25°C (3.73 mg cya-3-glu/100 g), and the other storage temperatures, respectively. The reduction of anthocyanins could be due to hydrolysis of the glycoside linkage or to the elevated temperature during jam processing which shifts the anthocyanins equilibrium toward the colorless chalcones [17]. The chalcones may be subjected to degradation via oxidation reactions during food processing, producing brown compounds or pigments with high molecular weight.

Physicochemical properties: The physicochemical properties including pH, soluble solids, and texture of strawberry fruit and its jam are shown in Table 2. It can be seen that the strawberry fruits had the highest pH values (3.50) followed by jam after processing (2.79), jam stored for 15 days at 25°C (2.76), and at the other storage temperatures, respectively. The decrease in pH during storage might be due to an increase in hydroxymethoxyfurfural (HMF) at elevated temperatures that converted into levulinic and formic acids, which was found to be high in strawberry [18, 19].

The soluble solids did not significantly change during storage or among storage temperatures. These results are in agreement with Javanmardi and Kubota who reported no significant changes in the soluble solids in tomatoes during postharvest storage at the 5°C and 25°C [20].

During storage, the firmness of strawberry jams (Table 2) gradually decreased from 0.55 to 0.69 N. However, the only significant decrease was at 55°C after 15 days of storage compared to other storage temperatures. These results were similar to those of Suutarinen *et al.* who reported that strawberry jam firmness was not significantly changed because cross linking between carboxyl groups of adjacent polyuronide chains via calcium ions made the cell wall less accessible to enzymes in the fruit that cause softening or to cell wall-degradation [21]. Jam firmness decreased after 15 days at 55°C that might be caused by the high temperatures encountered during jam making allowing pectin to undergo either acid or base catalyzed depolymerization [22].

Color: The attributes of three color parameters (L^*, a^*, b^*) were expressed by "E and chroma values. The color readings, "E and chroma are tabulated in Table 3. The fresh strawberries had the highest L^* values (40.63) followed by strawberry jam after processing (54.93) and the other storage temperatures. The redness values were the highest in the strawberry fruit (8.10) and decreased significantly after jam processing (5.65) and no significant difference during storage and among storage temperatures was observed. Similar results were reported by

Table 1. Changes in total phenolic, antioxidant capacity and total anthocyanin of strawberry jam during storage at different temperatures.

Material	Storage time(d)	Storage temp (°C)	Phenolics mg GAE/100 g	Antioxidant inhibition%	Anthocyanin mg cya-3-glu/100 g
fresh fruit	0	25	1693.55 ± 0.6 [a*]	84.91 ± 1.1 [a]	18.59 ± 0.6 [a]
jam	0	25	848.86 ± 0.9 [b]	59.38 ± 4.4 [b]	7.10 ± 0.9 [b]
jam	15	25	408.62 ± 0.2 [bc]	55.13 ± 5.4 [b]	3.73 ± 0.2 [c]
jam	15	35	131.46 ± 0.0 [c]	32.05 ± 0.8 [c]	3.24 ± 0.0 [cd]
jam	15	45	104.43 ± 0.2 [c]	29.82 ± 1.3 [c]	2.71 ± 0.2 [cd]
jam	15	55	77.285 ± 0.2 [c]	16.95 ± 1.0 [d]	2.24 ± 0.2 [d]

#All values are calculated as dry basis and means of three replicates.
*Means ± SD in the same column with the same letters are not significantly different ($P \leq 0.05$).

Table 2. Changes in pH, soluble solids, and firmness of strawbeery jam during storage at different temperatures.

Material	Storage time(d)	Storage temp (°C)	PH	Soluble solids (%)	Firmness (N)
fresh fruit	0	25	3.50 ± 0.02[a*]	8.02 ± 0.01 [b]	_
jam	0	25	2.79 ± 0.01[b]	70.16 ± 0.01 [a]	0.69 ± 0.04[a]
jam	15	25	2.76 ± 0.03[c]	70.13 ± 0.02 [a]	0.64 ± 0.01[a]
jam	15	35	2.72 ± 0.01[d]	70.12 ± 0.01 [a]	0.64 ± 0.04[a]
jam	15	45	2.71 ± 0.01[d]	70.07 ± 0.14 [a]	0.62 ± 0.03[ab]
jam	15	55	2.70 ± 0.01[d]	70.05 ± 0.35 [a]	0.55 ± 0.02[b]

#All values are calculated as dry basis and means of three replicates.
*Means ± SD in the same column with the same letters are not significantly different ($P \leq 0.05$).

Table 3. Changes in lightness (L^*), redness (a^*), and yellowness (b^*) , ‘‘E and chroma values of strawbeery during storage at different temperatures.

Material	Storage time(d)	Storage temp(°C)	L			a			b			ΔE			chroma		
fresh fruit	0	25	40.63	±	12.2 b	8.10	±	0.4 a	19.37	±	1.6 d	42.20	±	1 c	19.76	±	1.5 d
Jam	0	25	54.93	±	2.5 a*	5.65	±	0.3 b	36.88	±	2.4 c	64.60	±	3 b	22.91	±	2.4 c
Jam	15	25	54.73	±	8.1 a	5.37	±	1.6 b	37.00	±	3.8 c	66.60	±	9 b	39.87	±	3.9 bc
Jam	15	35	52.63	±	0.2 a	5.02	±	1.1 b	39.92	±	0.1 bc	66.73	±	0 b	42.68	±	0.0 ab
Jam	15	45	51.55	±	6.0 a	5.19	±	2.6 b	44.38	±	0.7 ab	68.23	±	4 b	44.67	±	1.1 ab
Jam	15	55	52.45	±	0.8 a	4.98	±	0.8 b	48.32	±	0.5 a	73.29	±	0 a	48.74	±	0.6 a

#All values are calculated as dry basis and means of three replicates.
*Means ± SD in the same column with the same letters are not significantly different ($P \leq 0.05$).

Ebeling and Montgomery who showed that the decrease in a^* values and anthocyanins pigments could be resulting from reactive quinones which degraded anthocyanins [23]. García-Viguera *et al.* [24] also reported that the degradation and loss of red color in strawberry jam could be due to maillard and non-enzymatic browning, ascorbic acid degradation and polymerisation of anthocyanins with other phenolics. The yellowness parameter (b^*) values in the strawberry fruit was lowest (19.37) and increased significantly after jam processing (36.88) followed by jam stored for 15 days at 45 and 55°C. The color changes observed in this study are in agreement with Shahnawaz and Sheikh who reported that a lighter color indicated loss of redness since anthocyanins and lutein pigments were sensitive to heat during jam processing, For the loss of original colors during storage at room temperature [25]. Abers and Wrolstad proposed that brown pigment formation rather than anthocyanins loss in strawberry jam could be the cause for a rapid loss of products original colours [26]. The ΔE value of the strawberry fruits was the lowest (42.20) among all the samples and increased significantly after processing (64.60). Furthermore, no significant difference in ΔE during storage and among storage temperatures was observed except at 55°C where a significant increase after a 15-day storage was recorded. The chroma value in the fresh berries was lowest (19.76) and increased significantly after processing (22.91) and after jam was stored for 15 days at 25°C (39.87), followed by other storage temperatures.

The correlation among the total phenolics, antioxidant activity, and anthocyanins: A strong relationship between total phenolics and antioxidant activity was found in strawberry jams, with a correlation coefficient $R^2 = 0.88$. Similar results of strawberry jam were reported by Patras *et al.* who found that the relationship between antioxidant activity and total phenolics was about 0.84 [6]. A strong relationship between total phenolics and anthocyanins was also found in strawberry jams as evidenced by a high correlation coefficient (R^2) of 0.95 between the two compound groups in strawberries.

Conclusions

The results showed that fresh strawberries had a significantly higher amount of total phenolics, antioxidant activity and anthocyanins than the processed counterparts. Jam processing decreased the concentrations of total phenolics, antioxidant activity and anthocyanins. The pH values decreased after jam processing, but the soluble solids increased after processing. The firmness decreased significantly only after storage at 55°C for 15 days. An increase in the lightness, yellowness, ΔE and chroma after jam processing of strawberry was observed while the redness decreased. The jams stored at 35 to 55°C had an increased yellowness and chroma, while the increase for the ΔE was only ascertained at 55°C. Despite the noticeable reduction in the total phenolics, antioxidant activity and anthocyanin compounds, jam processing still retained good amounts of these compounds during storage at different temperatures.

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