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Changes in chemical composition during storage of peaches (*Prunus persica*)

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Abstract Effects of storage time have been studied through 21 physical and chemical parameters in different batches of peaches stored at a controlled temperature (10–12 °C). The parameters were analyzed in order to assess possible differences between nutritional composition and consumer acceptability. The parameters studied were: weight, pH, titratable acidity, soluble solids (°Brix), moisture, vitamin C, soluble sugars, protein, dietary fiber (NDF, ADF, pectic substances), ashes, and mineral content (macroelements: Na, K, Ca, Mg, and P; microelements: Fe, Cu, Mg, and Zn). Analysis of variance revealed significant differences based on storage time and batch.

Key words Storage · Peaches · Physicochemical changes

Introduction

Fruits are a perishable food as their metabolic activity persists after harvest. Their respiratory processes continue, though more slowly, after harvest. Peaches are climateric stone fruit and therefore they are considered more perishable than those with seeds. Long-term storage is only possible in certain late cultivars. Their shelf life is limited by weight loss and physiological disorders, as well as browning and changes in texture [1, 2].

Technology leading to improve post-harvesting storage in fruit is fundamental for guaranteeing its quality from the initial production to the final stage of consumption [3–6]. Nowadays, proper arrangement and refrigerated transport of fruit for sale allows the rapid movement of fresh products from the country to the city, mainly through wholesale markets and from there to supermarkets and retail markets [7].

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Storage temperature is a key factor affecting the general metabolism of the fruit. At low temperatures, CO_2 and ethylene production is low and climateric respiration is delayed [8]. In line with this, the International Standards Organization (ISO) states that the optimal storage temperature for peaches ranges from −1 °C to +2 °C and the mean life expected under such conditions may range from 2 weeks to 4 weeks [9]. Salunkhe and Desai [3] find the same results for peaches at 0 °C. Robertson et al. [10] studied Cresthaven variety peaches stored at 0 °C for different time periods and observed that storage time has very little effect over 4 weeks.

Nutritive quality in fruit is determined by physical and chemical changes taking place during conservation and storage. Evaluation of these changes may be established by the modifications in sensory and chemical characteristics indicating alterations in the nutritive value.

The purpose of this study was to evaluate whether significant changes occur in the chemical components of peaches during storage under controlled temperature conditions (10–12 °C). It is intended to serve as a guideline study for both trader and consumer.

Materials and methods

Fruit samples. Peach fruits (*Prunus persica* L. Batsch) were purchased in wholesale markets in Madrid with the minimum grade of maturity to be commercialized. Three differents batches of fruits (24 fruits each) were consecutively selected and stored in a control chamber at 10–12 °C. The fruits were sampled immediately after arriving at the laboratory, and then at 2–3 days intervals during the time they were suitable for human consumption. Representative samples were analyzed in triplicate.

The fruits were weighed, peeled, sliced, and dried (Telstar Freeze-Dried, model Cryodos) on every sampling day. The parameters which required immediate analysis were established in fresh fruit.

Analytical methods. General parameters were measured following official methods [11, 12]. Moisture content was determined by weight loss; pH was measured with a pH meter (Orion-Research, model 701); titratable acidity (expressed as percentage of malic acid) was measured with 0.1 N NaOH up to pH 8.1; soluble solids, reported as degrees Brix, were determined with a digital refractometer (Atago), protein was analyzed by the Kjeldahl method ($N \times 6.25$), and ashes were obtained by incineration in a muffle furnace at 550 °C.

Vitamin C was extracted with metaphosphoric acid and determined by the Brubacher fluorimetric method [13]. Soluble sugars (expressed as percentage of glucose) were quantified according to the anthrone spectrophotometric method, with previous extraction using 85% hot methanol [14]. For the neutral detergent fiber (NDF) and acid detergent fiber (ADF) analysis, the detergent methods originally described by Van Soest [15] were used. Pectic substances (expressed as percentage of galacturonic acid) were determined using the spectrophotometric method based on the color reaction with 3-phenylphenol [16].

Mineral content: macroelements (Na, K, Ca, and Mg) and microelements (Fe, Mn, Cu, and Zn) were analyzed by means of atomic absorption spectroscopy (Perkin Elmer, model 2280), having previously mineralized the sample [11]. Phosphorus was determined by a colorimetric method [12].

Precision assays were performed for analytical methods, and the coefficients of variation obtained in all cases were under 6%.

Statistical analysis. Data were statistically evaluated by analysis of variance (ANOVA) and means were compared using Duncan's test at $P<0.05$ to determine the significant differences that could be attributed to time of storage. Two-way analysis of variance was performed in order to establish the incidence of batch and storage time factors.

Results and discussion

Study of the storage of peaches was carried out over 13 days, as it is at this time that deterioration in the sensorial characteristics of the fruit becomes most evident. The physical and chemical changes reported during storage of the peaches are shown in Tables 1–4. This evaluation was performed on three batches of different peaches in order to compare the evolution trends of the main constituents analyzed under the established conditions.

Weight changes in the fruit pieces showed a significant decrease as storage time increased (Table 1). Weight losses were similar in the three batches and account for approximately 17% after 13 days of storage. These changes in weight were statistically significant ($P<0.01$) in all batches.

During storage, a slight though significant increase ($P<0.01$) in the moisture content occurred in all the batches analyzed, together with greater juiciness in the peaches and a significant loss of firmness. However, the moisture increase was below 2% since there was substantial evaporation due to environmental conditions.

All batches had a similar pH, with a gradual increase during the storage period. Changes occurring between

Table 1 Changes in general parameters of peach fruits during storage (expressed as fresh weight)

Storage days	Weight of fruit (g)	Moisture (g%)	pH	Titratable acidity (g% malic acid)	Soluble solids (°Brix)
Batch I					
0	161 a	87.66 d	3.81 d	1.02 a	10.20 f
3	154 b	88.01 c	3.85 cd	0.97 b	10.50 e
6	152 c	88.04 d	3.80 cb	0.95 b	10.80 d
9	150 b	88.45 a	3.92 b	0.88 c	11.80 c
11	143 c	88.79 a	3.94 b	0.88 c	12.40 b
13	134 d	88.85 a	4.45 a	0.85 c	12.65 a
[1] Significance	**	**	**	**	**
Batch II					
0	152 a	89.09 d	3.52 d	1.16 a	7.66 d
3	148 b	89.61 c	3.54 d	1.01 b	8.40 c
6	147 b	90.39 b	3.57 cd	0.96 c	8.50 b
9	145 b	90.94 a	3.62 c	0.83 d	8.90 b
11	137 c	90.96 a	3.71 b	0.78 e	9.02 ba
13	126 d	90.78 a	3.83 a	0.76 e	9.20 a
[1] Significance	**	**	**	**	**
Batch III					
0	150 a	88.25 d	3.76 e	1.07 a	9.59 f
3	143 b	88.79 c	3.78 e	1.03 a	10.04 e
6	141 cb	88.91 b	3.94 d	0.92 b	11.0 d
9	138 c	89.11 b	3.99 c	0.89 b	11.70 c
11	129 d	89.73 a	4.21 b	0.77 c	12.41 b
13	124 a	89.56 a	4.60 a	0.73 c	12.93 a
[1] Significance	**	**	**	**	**
[2] Batch	**	**	**	*	**
Time	**	**	**	**	**
B*T	ns	**	**	**	**

[1] One-way ANOVA: ** $P<0.01$, * $P<0.05$, *ns* = not significant, *a–f* means followed by different letters in the same column are significantly different ($P<0.05$)

[2] Two-way ANOVA: ** $P<0.01$, * $P<0.05$, *ns* not significant

the measurements taken throughout the evaluation showed significant differences ($P<0.01$) between the first and the last day of storage. Acidity was closely associated with pH and evolved similarly, though the two were inversely correlated. The total decrease in acidity during storage was high, about 30% after storage.

Soluble solids are another important parameter to indicate the stage of ripeness and the acceptability of peaches. Brady [17] has shown that sugars represent 60–80% of soluble solids in peaches. In all the batches analyzed a gradual increase in soluble solids occurred from the first to the last day ($P<0.01$). Changes observed between sampling days in batches I and III were statistically significant, whereas batch II stabilized on certain intermediate days where differences were not significant. The soluble solids increased about 26% after 13 days of storage.

The vitamin C content increased significantly in batches II and III ($P<0.01$ for both), whereas no significant differences were found in batch I during the storage period (Table 2). A small decrease was observed in batches I and III after 11 days of storage. Losses in vitamin C were associated with senescence and deterioration of the fruit [18].

The soluble sugars fraction showed a slight evolution for each batch. No significant increase was observed during storage. The three batches showed similar behaviour; the observed increments ranged from 4% to 10%. Weichmann and Hansen [19] reported that the carbohydrate content in vegetables changes because it is the most important energy substrate in the different metabolic processes that continue after harvesting the product.

The protein fraction decreased throughout storage. Changes occurring during this storage were only significant in batches I and II ($P<0.01$ and $P<0.05$, respectively), though differences between consecutive dates were not very remarkable.

Only small changes in dietary fiber were observed in all batches between the first and last day of storage. Therefore the changes taking place during the period of storage were not considered significant. The dietary fiber content was considered as the sum of NDF and pectic substances. The NDF and ADF fractions slightly decreased (Table 3), but these changes were only considered statistically significant in batch III ($P<0.05$), where losses between the first and last day of storage were 2% in the NDF fraction and 14% in the ADF fraction. For pectic substances, increasing values were generally observed. This ascending evolution had different slopes for each batch. This trend could be translated into a decrease in the protopectin content and an increase in the soluble pectin fraction. Differences reported were statistically significant in batches I and III

Table 2 Changes in chemical composition of peach fruits during storage (expressed as fresh weight)

Storage days	Vitamin C (mg%)	Protein (g%)	Soluble sugars (g%)	Dietary fiber (g%)	Ash (g%)
Batch I					
0	7.25	1.31 a	9.31	1.14	0.32 b
3	7.38	1.24 a	9.25	1.26	0.31 b
6	7.42	0.99 b	9.31	1.29	0.31 b
9	7.51	0.92 cb	9.56	1.25	0.37 ba
11	7.73	0.88 cb	9.69	1.19	0.44 a
13	6.65	0.83 c	9.75	1.17	0.41 a
[1] Significance	ns	**	ns	ns	*
Batch II					
0	2.36 c	1.29 a	7.41	0.99	0.43
3	2.92 cb	1.10 bc	7.45	1.01	0.36
6	2.96 cb	1.10 bc	8.21	0.98	0.35
9	3.09 b	1.03 c	8.11	0.96	0.33
11	5.41 a	1.16 b	8.09	0.96	0.35
13	5.77 a	1.20 ba	8.17	1.03	0.38
[1] Significance	**	*	ns	ns	ns
Batch III					
0	5.15 d	1.07	8.68	1.11	0.35
3	5.92 c	0.96	8.85	1.09	0.34
6	6.96 b	0.82	9.93	1.08	0.32
9	7.93 a	0.80	9.31	1.04	0.32
11	7.97 a	0.73	8.85	0.98	0.29
13	7.21 b	0.76	9.01	1.00	0.31
[1] Significance	**	ns	ns	ns	ns
[2] Batch	**	ns	**	**	**
Time	**	ns	ns	ns	ns
B*T	**	ns	ns	ns	**

[1] One-way ANOVA: ** $P<0.01$, * $P<0.05$, *ns* not significant, *a–d* means followed by different letters in the same column are significantly different ($P<0.05$)
[2] Two-way ANOVA: ** $P<0.01$, * $P<0.05$, *ns* not significant

Table 3 Changes in fiber fraction of peach fruits during storage (g per 100 g fresh weight)

Storage days	NDF	ADF	Pectic substances
Batch I			
0	0.99	0.77	0.15 c
3	1.01	0.76	0.25 b
6	1.00	0.72	0.29 a
9	0.95	0.73	0.30 a
11	0.88	0.68	0.31 a
13	0.86	0.61	0.31 a
[1] Significance	ns	ns	**
Batch II			
0	0.80	0.57	0.19
3	0.81	0.65	0.20
6	0.78	0.64	0.20
9	0.77	0.57	0.19
11	0.76	0.63	0.20
13	0.82	0.65	0.21
[1] Significance	ns	ns	ns
Batch III			
0	0.90 a	0.68	0.21 c
3	0.84 ba	0.64 ba	0.25 b
6	0.80 bac	0.63 bac	0.28 ba
9	0.75 c	0.61 bdc	0.29 ba
11	0.70 c	0.57 d	0.28 ba
13	0.70 c	0.58 dc	0.30 a
[1] Significance	*	*	*
[2] Batch	**	ns	**
Time	ns	ns	**
B*T	ns	ns	**

[1] One-way ANOVA: ** $P<0.01$, * $P<0.05$, *ns* not significant, *a–d* means followed by different letters in the same column are significantly different ($P<0.05$)
[2] Two-way ANOVA: ** $P<0.01$, * $P<0.05$, *ns* not significant

($P<0.01$ and $P<0.05$ respectively), whereas in batch II the increase was not significant after 13 days of storage.

No remarkable changes in ash values occurred during the whole storage period of this evaluation. Slightly significant changes were only observed in batch I ($P<0.05$). Weichmann [20] showed that mineral losses are low after harvesting vegetables, as well as during storage prior to consumption. A few changes occurred in the mineral fraction; however, the different macro- and microelements have been studied to gather detailed information on the mineral characterization of peach fruit.

The mineral fraction in peaches was considered closely associated with the mineral composition of the soil and with the applied fertilizers. In this study, significant differences ($P<0.01$) were observed for each individual mineral between batches except for the phosphorus content (Table 4). Potassium was the major macroelement of peach fruit, and represented about 80% of the total content. This mineral plays an important role in ion balance and contributes to maintenance of

Table 4 Changes in mineral contents of peach fruits during storage (mg per 100 g fresh weight)

Storage days	K	Na	Ca	Mg	P	Fe	Cu	Zn	Mn
Batch I									
0	177.10 a	4.92	9.12 a	9.93 a	19.03	0.18 a	0.15 a	0.15	0.06
3	159.8 b	4.20	8.11 a	9.58 a	19.60	0.16 b	0.11 ab	0.14	0.06
6	173.0 ab	4.17	8.14 a	9.43 a	18.66	0.15 b	0.11 ab	0.13	0.06
9	161.70 ab	3.51	6.14 b	8.24 b	18.89	0.12 c	0.07 b	0.09	0.04
11	126.20 c	3.31	5.72 b	7.30 c	16.51	0.12 c	0.07 b	0.08	0.04
13	168.35 ab	3.37	5.58 b	7.59 bc	17.57	0.11 c	0.09 b	0.1	0.04
[1] Significance	**	ns	**	**	ns	**	*	ns	ns
Batch II									
0	240.80 a	2.94	5.10	8.62 a	21.93	0.24 a	0.09	0.13	0.09
3	223.30 b	3.02	4.82	8.01 ab	19.88	0.25 a	0.08	0.14	0.08
6	205.64 c	2.08	4.55	7.18 b	18.58	0.21 b	0.07	0.13	0.08
9	199.00 c	2.63	4.38	7.16 b	18.51	0.21 b	0.07	0.13	0.07
11	198.79 c	2.91	4.30	7.14 b	19.30	0.20 b	0.07	0.12	0.07
13	221.12 b	2.68	4.61	7.40 b	19.93	0.21 b	0.07	0.12	0.07
[1] Significance	**	ns	ns	*	ns	*	ns	ns	ns
Batch III									
0	201.10 a	3.88	7.50 a	9.11 a	20.72 a	0.20 a	0.12	0.13	0.07
3	195.13 b	3.50	7.42 a	8.81 a	20.33 a	0.19 a	0.11	0.13	0.07
6	183.51 c	3.45	7.20 a	8.67 ab	19.65 ab	0.17 b	0.1	0.13	0.07
9	170.11 d	3.55	7.18 a	8.11 b	18.96 ab	0.16 bc	0.1	0.13	0.07
11	180.13 c	3.70	6.10 b	6.81 c	18.00 b	0.15 c	0.09	0.12	0.07
13	194.77 b	3.71	5.66 b	7.00 c	18.23 b	0.15 c	0.1	0.13	0.07
[1] Significance	**	ns	**	**	*	**	ns	ns	ns
[2] Batch	**	**	**	**	ns	**	**	**	**
Time	**	ns	**	**	*	**	**	**	**
B*T	**	**	**	**	ns	ns	ns	ns	ns

[1] One-way ANOVA: ** $P<0.01$, * $P<0.05$, *ns* not significant, *a–d* means followed by different letters in the same column are significantly different ($P<0.05$)
[2] Two-way ANOVA: ** $P<0.01$, * $P<0.05$, *ns* not significant

cell organization and permeability; it also can activate certain enzymes. Phosphorus, calcium, and magnesium were found in lower concentrations, and the lowest mean values corresponded to sodium. The K/Na ratio is very high in peaches, for this reason it could be a suitable fruit in diets for hypertensive disease. The mean values of the microelements showed the sequence Fe>Zn>Cu>Mn in all batches.

The influence of storage on the individual mineral content was minimal. The most significant changes in storage were observed for potassium, calcium, magnesium, and iron (different significance levels were found in each batch). The other minerals exhibited a moderate change that was not significant throughout the storage period.

Finally, the results of the two-way ANOVA showed that storage time and the batch were important factors when studying the effects of storage in peaches, especially on the following parameters: weight, moisture, pH, acidity, soluble solids, vitamin C, and pectic substances. The significant differences between batches could be explained by growing conditions, harvest time, and origin. The interaction effect (storage time $\times$ batch) was not significant for weight, soluble sugars, protein, dietary fiber, phosphorus, and microelements. This indicates that all the batches showed similar trends over the storage period.

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