Food Chemistry 80 (2003) 445–450

Food Chemistry

www.elsevier.com/locate/foodchem

Effects of current storage conditions on nutrient retention in several varieties of potatoes from Tenerife

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Received 22 March 2002; received in revised form 17 June 2002; accepted 17 June 2002

Abstract

The evolution of moisture, starch, amylose, ash, fructose, sucrose, glucose and ascorbic acid was studied in five cultivars of Tenerife potatoes in order to evaluate their variation during storage at 12 °C and 90% humidity. Differences in behaviour were detected among cultivars in relation to the period of storage under these conditions. The Negra cultivar presented the worst behaviour in storage, while the Bonita and Colorada cultivars presented the best. The moisture remained constant for the first 6 weeks; afterwards; a significant decrease was observed. A progressive decrease of starch (dry basis) over the time of storage was detected, while an increase of reducing sugars occurred. The amylose/amylopectin ratio increased during the first 6 weeks of storage. The concentration of vitamin C decreased markedly during the storage, and, after the 20th week, the content had decreased by more than 50%.

Keywords: Evolution of chemical composition; Cultivars of potatoes; Storage; Tenerife

1. Introduction

From potato harvest to consumption there are many factors that produce changes in chemical composition and, as a consequence, in nutritional value. Changes are mainly produced during storage and culinary processes. Three variables determine chemical changes of potatoes during storage: the initial status of the potatoes, time and conditions of storage (Burton, van Es, & Hartmans, 1992). So, inadequate conditions of storage result in high losses, even in a good product, while good storage can merely limit storage losses over relatively long periods. The storage changes are mainly caused by the influences of respiration, transpiration, sprouting, diseases or presence of pest (Burton et al., 1992; Gravouill, 1999; Storey & Davies, 1992). The storage changes can produce decreases in weight and changes related to quality, such as appearance, flavour, texture and chemical composition.

The consumption of the Canary population is high: 166.3 and 122.7 g per day for men and women, respectively (Serra-Majen, Armas Navarro, & Ribas Barba, 1999). Approximately 20–25 cultivars of potato are produced and consumed in the Canary Islands (Gil González, 1997), which are commonly grouped into two main types: (1) traditional potatoes or "*Papas antiguas de Canarias*", which belong to the cultivars *Solanum tuberosum* ssp. *andigena, Solanum tuberosum* ssp. *tuberosum* and *Solanum*×*chaucha* cultivars and were introduced into the islands several centuries ago. It is supposed that they are closely associated to the potatoes from the Andes; (2) potatoes which have been imported from the British Isles during the past century. These latter cultivars belong to *S. tuberosum* ssp. *tuberosum*.

The conditions for storage used in the Canary Islands (12 °C and 80–90% humidity) are adequate to avoid sweetening, although sprouting in several cultivars can be produced in long-term storage. It is important to know the changes of chemical composition because they can represent significant losses in the nutritional value of the potatoes. However, there are no studies on storage conditions for potatoes from Tenerife, especially for traditional cultivars. In this paper we examine the

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PII: S0308-8146(02)00281-9

variations of chemical composition and nutritional value of potatoes, during the post-harvest period, under current storage conditions used in Tenerife.

2. Materials and methods

2.1. Samples

The following cultivars: Negra (*Solanum × chaucha*); Bonita and Colorada (*S. tuberosum* spp. *andigenum*); and Kerr's Pink and Cara (*S. tuberosum* spp. *tuberosum*) were selected for their economic importance. Forty three samples of potatoes were provided by Mercatenerife (Central Market of Tenerife) from different farms located in several regions of the island. Potato samples were collected in several regions to diminish the environmental influence. Table 1 shows the main characteristics of the potato samples. They were harvested between March and July 2000 and no more than two weeks passed between harvest and analysis. The analysed cultivars were Cara ($n=10$) and Kerr's Pink ($n=10$) from *S. tuberosum* ssp. *tuberosum*, Bonita ($n=5$) and Colorada ($n=6$) from *S. tuberosum* ssp *andigena* and Negra ($n=12$) from *Solanum × chaucha*. After sampling, the potatoes were weighed and immediately analysed for moisture, ash and ascorbic acid. Also, they were processed adequately for analysing starch, amylose and sugars.

Tests were carried out immediately after harvest and after 6 and after 20 weeks of storage. The potatoes were stored according to the normal storage conditions in the Canary Islands (12 °C and 80–90% humidity).

2.2. Analytical methods

Between 3 and 6 fresh and whole tubers of each sample of potato were well homogenised using a Turmix (T-25 Basic, Ika). Approximately 80 g of this homogenised mix were divided into three fractions: (1) 10 g were used for determining amylose and sugars, (2) 3 g were used for each determination of moisture and ash; (3) 50 g were desiccated to 55 °C (96 h) for determining starch.

Table 1
Distribution of potato cultivars according to harvested time and production area

Cultivar	Tuber weight (g)	Harvested time	Location of farms	
			North	South
Bonita ($n=5$)	35±14	March–July	3	2
Cara ($n=10$)	94±39	April–June	5	5
Colorada ($n=6$)	54±24	April–June	6	0
Negra ($n=12$)	30±9	March–June	6	6
Kerr's Pink ($n=10$)	97±19	March–July	5	5

All the determinations were carried out in duplicate. The analysis of ascorbic acid was independently carried out on three tubers in duplicated sub-samples.

Sprout growth was measured with a ruler, at 6 and 20 weeks, on three tubers from each sample. The lengths of every sprout of each tuber were added to obtain the total linear length of sprouts of each tuber.

Moisture was determined in three replicates by desiccation at 105 °C for 24 h, according to the method described in AOAC (1990). Ash was determined in triplicate, by ashing the residue from moisture determination at 550 °C for 24 h. The remaining analyses were also performed in duplicate. Starch was determined by a polarimetric method, according to Egan, Kirk, and Sawyer (1987). Amylose content was determined according to the method proposed by Hovenkamp-Hermelink, De Vries, Adamse, and Jacobsen (1998). Ascorbic acid was determined by the dichlorophenol indophenol titration procedure (AOAC, 1990). Ascorbic acid was extracted using acetic acid and metaphosphoric acid solution.

Sugar analysis was performed by HPLC [Shimadzu chromatograph, with a RID-6A detector and an Aminex HPX-87C (250×4 mm) column (BioRad)]. Sorbitol was used as the internal standard. Soluble sugars were extracted with 5 ml of a hot 80% ethanol solution (and then freeze-dried) (Peris-Tortajada, 1996). The dried extract was then re-dissolved in 4 ml of ultra pure water and passed through a C_{18} Sep-pack and through a column with Amberlite resin IRA-400 (Cl) (BDH). Finally, the sample was filtered through a PVDF 0.45 μm filter. Glucose, fructose and sucrose concentrations were determined by injecting 20 μl of the standard solutions or sample extracts and by eluting with ultra pure water.

All the chemical parameters studied were submitted to quality control. In a previous paper (Casañas, González, Rodríguez, Marrero, & Díaz, in press) we included the results of this study.

2.3. Statistics

All statistical analyses were performed by means of the SPSS version 10.0 software for Windows. The Kolmogorov–Smirnov's test was applied to verify whether the variable had a normal distribution, $P<0.05$. The mean values obtained in the different groups were compared by one-way ANOVA and *t*-test, assuming that there were significant differences between mean values when statistical comparison gave $P<0.05$.

3. Results and discussion

The size of sprout, after 6 and after 20 weeks for the studied cultivars, is shown in Table 2. Large sprout growth was observed in the Negra cultivar, presenting a mean size of 44.8±40.7 and 55.4±59.6 cm/tuber after 6 and after 20 weeks of storage, respectively. The cultivars that showed the best behaviour regarding sprout growth were Colorada and Bonita, with sizes of 1.8±3.4 and 8.5±16.7 cm/tuber, respectively, after 20 weeks. Table 3 shows the changes of the water content in the five considered cultivars, including the mean change for all the samples. No significant differences were found between the mean concentrations of any samples after 6 weeks of storage, although a slight trend to desiccation was observed. However, a significant ($P<0.05$) loss of water was observed in Negra and Kerr's Pink as well as in all the studied samples as a group after 20 weeks. The moisture decrease found after 20 weeks of storage may be connected with the increase in the transpiration of the tubers produced due to sprouting (Booth & Shaw, 1989; Burton et al., 1992). This increase of the evaporation process is due to the increase of the permeability of the epidermis of the sprouts and the increase of the evaporation surface (Booth & Shaw, 1989; Burton et al., 1992; Gandarias & Lobo, 1975). In contrast, Bonita, Cara and Colorada did not undergo significant changes throughout storage. The Negra cultivar showed the worst behaviour in this respect. A large number of potato samples belonging to that cultivar displayed deficient characteristics which would affect consumption. The tubers presented an inadequate texture, due to large water loss, as well as the presence of pests such as aphids. This agrees with Chico Marrero (1986) who suggests that this cultivar has a very short dormancy period. Burton et al. (1992) have indicated a maximum loss of 5%, above which an unacceptable modification of texture, turgidity and freshness of the product is produced. Losses higher than this percentage were only found in the Negra variety, and, therefore, its commercial value can be considered as lost.

Evolution of ash concentrations (referred to wet or dry weight) for the five cultivars of potatoes and all the potato samples is shown in Table 4. Small changes observed in the ash content refer to wet or dry weight, depending on time of storage. This agrees with Burton et al. (1992) and Hägg, Häkkinen, Kumpulainen, Ahvenainen, and Hurme (1998), who indicated that the amount and chemical compositions of potatoes are

Table 2
Evolution of sprout growth (cm/tuber) in the storage period

Cultivars	Storage time (weeks)	
	6	20
Bonita	5[a]	5
	0.0±0.0 a[b]	8.5±16.7 a
Cara	10	10
	0.4±0.4a	21.0±10.0a
Colorada	5	4
	0.0±0.0a	1.8±3.4 a
Negra	11	8
	44.8±40.7a	55.4±59.6 b
Kerr's Pink	5	5
	0.0±0.0a	26.9±9.7b
Total	37	28
	9.0±24.7 a	21.7±35.5 b

Values in the same row with the same letter present a significance level of $P>0.05$.
[a] Number of samples.
[b] Average±standard deviation.

Table 3
Evolution of moisture (g/100 g) in the storage period

Cultivars	Storage time (weeks)		
	0	6	20
Bonita	5[a]	5	5
	77.1±1.22.a[b]	76.8±1.7a	76.4±1.5a
Cara	10	10	10
	81.9±1.8a	81.5±1.2a	80.4±2.3a
Colorada	6	6	6
	76.2±2.5a	75.3±1.6a	74.1±1.1a
Negra	12	11	8
	77.5±2.0a	76.8±2.1a	69.9±4.6b
Kerr's Pink	10	10	7
	78.1±2.0a	78.3±1.6a	75.6±1.6b
Total	43	42	33
	78.4±2.8a	78.1±2.7a	75.5±3.6b

Values in the same row with the same letter present a significance level of $P>0.05$.
[a] Number of samples.
[b] Average±standard deviation.

Table 4
Evolution of ash (g/100 g) in the storage period

Cultivars	Storage time (weeks)		
	0	6	20
Bonita	5[a]	5	5
	(a) 1.07±0.10[b]a	a) 1.14±0.05a	a) 1.15±0.09a
	(b) 4.70±0.51a	(b) 4.96±0.38a	(b) 4.79±0.31a
Cara	10	10	9
	(a) 1.03±0.12a	(a) 1.06±0.12a	(a) 1.02±0.15a
	(b) 5.75±0.66a	(b) 5.71±0.50a	(b) 5.22±0.81a
Colorada	6	6	5
	(a) 1.13±0.15a	1.18±.06a	1.09±0.15a
	(b) 4.78±0.81a	(b) 4.78±0.39a	(b) 4.25±0.73
Negra	12	11	8
	(a) 1.18±0.12a	(a) 1.19±0.13a	(a) 1.40±0.28b
	(b) 5.26±0.66a	(b) 5.16±0.68ab	(b) 4.55±0.64ab
Kerr's Pink	10	10	7
	(a) 1.20±0.08a	(a) 1.19±0.13a	(a) 1.19±1.12a
	(b) 5.53±0.69a	(b) 5.50±0.47a	(b) 4.95±0.48a
Total	43	42	33
	(a) 1.13±0.13a	(a) 1.15±0.12a	(a) 1.16±0.21a
	(b) 5.30±0.76a	(b) 5.29±0.60a	(b) 4.80±0.70b

Values in the same row with the same letter present a significance level of $P>0.05$. (a) fresh basis. (b) dry basis.
[a] Number of samples.
[b] Average±standard deviation.

slightly modified by long-term storage. During the storage of the tubers, several processes (transpiration, respiration and redistribution, caused by sprouting) may affect the ash concentrations. Transpiration causes water loss, and as a consequence increases the concentration of all the constituents of the dry matter. Losses of dry matter are produced by the respiration process. When the data of the ash are expressed on a wet weight basis, a slight but insignificant increase ($P > 0.05$) was observed in the Bonita and Negra varieties. The other cultivars did not show appreciable differences. Higher changes were found regarding the data on a dry weight basis. Therefore, decreases of the ash contents after 20 weeks of storage were observed in all the cultivars except the Bonita variety. The decrease observed in the Negra cultivar was significant ($P = 0.039$). This could be due to the mineral redistribution produced during sprouting.

Table 5 shows the variation of starch concentrations (referred to as wet and dry weight) during storage for all potato samples as a group and for the samples belonging to each cultivar. After 6 weeks of storage, no important changes in the starch concentrations (wet or dry weight) were produced. However, if the data refer to dry weight, significant ($P < 0.05$) decreases were observed after 20 weeks of storage in all the cultivars and in all the samples taken together. These results agree with those indicated by Biemelt, Hajirezaei, Hentschen, and Sonnewald (2000) who observed that the growth of the sprouts in stored potatoes depends on the degradation by hydrolysis of the starch. This starch degradation produces enough energy and matter to maintain growth and development of the sprouts. The values referring to wet weight present different behaviour. So, in general, no important changes were found. This is due to the fact that starch losses are compensated by the water losses as a consequence of transpiration. In contrast, the Negra cultivar showed a significant increase in starch concentration after 20 weeks of storage. In this case, the large water losses observed (9.8%) produced an increase of starch concentration. An increase of amylose (% respect to starch) during the storage of all the cultivars was observed (Table 6). It could be due to the activity of glucoamylases, which are debranching enzymes that break the α-1→6 links of amylopectin, generating molecules of linear amylose (Marchal, 1999). Besides, increases of reducing sugars and sucrose are produced during the hydrolysis of starch. These increases are used for respiration, but they also contribute to Maillard reactions and to the sugar taste. This is a non-desirable feature for both consumption and industrial processing. It is well known that this production of sugars is heavily affected by the storage temperature. Therefore, below 10–12 °C both reducing sugars (glucose and fructose) and non reducing sugars (sucrose) are synthesised to an increasing degree (Burton et al., 1992). However, the main problem of these high temperatures is the appearance of sprouting on the tubers and a devaluation of their commercial value. Table 7 shows the results for the reducing sugars (glucose and fructose) and sucrose found immediately after harvest and after 20 weeks of storage for potato samples as a group, and grouping of the potato samples according to cultivar. The determination of these parameters in the 6th week was not carried out because the starch

Table 5
Evolution of starch (g/100g) in the storage period

Cultivars	Storage time (weeks)		
	0	6	20
Bonita	5[a]	5	5
	(a) 16.8±1.4[b]a	(a) 16.4±1.4a	(a) 15.3±1.8a
	(b) 73.6±2.62a	(b) 70.6±2.4a	(b) 63.5±2.8b
Cara	10	10	9
	(a) 13.1±1.5a	(a) 13.3±1.0a	(a) 13.0±2.3a
	(b) 72.2±1.5a	(b) 72.0±1.5a	(b) 66.2±5.5b
Colorada	6	6	5
	(a) 17.5±2.7a	(a) 17.9±1.2a	(a) 15.9±0.9a
	(b) 73.1±4.6a	(b) 72.6±2.6a	(b) 61.7±4.5b
Negra	12	11	8
	(a) 16.0±1.7a	(a) 16.5±1.7a	(a) 18.6±2.7b
	(b) 70.8±2.5a	(b) 71.1±1.6a	(b) 62.2±4.4b
Kerr's Pink	10	10	7
	(a) 15.8±1.5a	(a) 15.6±1.4a	(a) 16.2±1.7a
	(b) 72.4±2.2a	(b) 71.8±1.7a	(b) 66.2±4.4b
Total	43	42	33
	(a) 15.6±2.24a	(a) 15.7±1.9a	(a) 15.8±2.9a
	(b) 72.1±2.7a	(b) 71.6±4.2a	(b) 64.2±4.8b

Values in the same row with the same letter present a significance level of $P > 0.05$. (a) fresh basis. (b) dry basis.
[a] Number of samples.
[b] Average±standard deviation.

Table 6
Evolution of amylose (g/100 g of starch) in the storage period

Cultivars	Storage time (weeks)		
	0	6	20
Bonita	5[a]	5	5
	25.6±3.12[b]a	25.4±5.1a	28.2±6.2a
Cara	10	10	9
	26.6±2.8a	28.3±3.8a	32.3±2.3b
Colorada	6	6	5
	22.3±3.7a	25.4±5.0a	27.7±5.4a
Negra	12	11	8
	23.9±3.2a	28.4±4.3b	30.3±3.8b
Kerr's Pink	10	10	7
	24.2±2.7a	26.5±4.6a	33.1±4.8b
Total	43	42	33
	24.6±3.2a	27.1±4.4b	30.8±4.5c

Values in the same row with the same letter present a significance level of $P > 0.05$.
[a] Number of samples.
[b] Average±standard deviation.

had not significantly degraded and the amylose/amylopectin ratio stayed relatively constant.

The variation of the ascorbic acid during the time of storage, for all the potato samples and the five cultivars, is presented in Table 8. According to several authors (Burton et al., 1992; Hägg et al., 1998; Keijbets & Ebbenhorst-Seller, 1990; Mondy & Munshi, 1993; Storey & Davies, 1992), the content of ascorbic acid decreases significantly during storage. This decrease of ascorbic acid is due to oxidation to dehydroascorbic and later to diketo-gluconic acid. The vitamin C losses can be estimated by only analysing ascorbic acid because the dehydroascorbic acid represents less than the standard deviation of the ascorbic acid. The ascorbic acid losses depend on the cultivar, location, maturity, time of harvest and conditions of storage. The results obtained in this paper indicate that there are significant decreases of ascorbic acid in all the samples as a group and in each cultivar. There are differences in the ascorbic acid losses among the cultivars after 6 weeks of storage. In this period, the decreases were significant ($P<0.05$) for all the samples taken together and for the potato samples belonging to the Colorada and Kerr's Pink cultivar. These results agree with those of Keijbets and Ebbenhorst-Seller (1990) who found that initial loss patterns differ between samples as a function of the cultivar, location and season but, at the end of the storage period, losses were very similar in all the samples. The losses of vitamin C at the end of the period were significant for all samples as a group and for each cultivar ($P<0.001$). These losses were between 53 and 63% which represent an significant loss in the nutritional value of the product. These results agree with those reported by Mondy and Munshi (1993) and Keijbets and Ebbenhordt-Seller (1990), who found that the decreases of ascorbic acid during 24 weeks of storage were between 50 and 60%.

The current conditions used in the Canary Islands for storing potatoes can be considered adequate for the Bonita and Colorada cultivars. However, conditions for the Negra and Cara varieties should be revised. Kerr's Pink can be stored under those conditions for at least 6 weeks. In a future paper we will study the effects of different storage conditions on several cultivars.

Table 7
Evolution of soluble sugars (mg/100g) in the storage period

Cultivars	Storage time (weeks)			
	Reducing sugars		Sucrose	
	0	20	0	20
Bonita	4[a]	3	5[a]	4
	108±53.7[b]a	153±51.1a	350±223.[b]a	339±50.6a
Cara	9	4	9	4
	85.8±57.0a	246±87.4b	353±182a	232±122a
Colorada	6	4	6	4
	171±151a	245±36.6a	431±220a	454±66.9a
Negra	12	5	12	5
	83.1±56.6a	260±41.5b	335±49.2a	1423±883b
Kerr's Pink	10	5	10	5
	44.1±16.0a	242±34.3b	315±42.4a	522±183b
Total	41	21	41	22
	89.0±79.5a	235±58.5b	350±137a	642±613b

Values in the same row with the same letter present a significance level of $P>0.05$.
[a] Number of samples.
[b] Average±standard deviation.

Table 8
Evolution of ascorbic acid (mg/100 g) in the storage period

Cultivars	Storage time (weeks)		
	0	6	20
Bonita	5[a]	5	5
	21.6±3.9[b]a	19.9±3.7a (7.9%)	9.1±1.2b (57.9%)
Cara	10	10	9
	25.7±5.6a	22.7±4.2a (11.7%)	11.5±3.4b (55.3%)
Colorada	6	6	5
	21.4±5.6a	15.7±2.6b (26.6%)	10.0±2.2c (53.3%)
Negra	12	11	8
	24.2±6.5a	22.1±5.0a(8.7%)	9.0±2.4b (62.8%)
Kerr's Pink	10	10	7
	24.9±5.0a	20.3±2.9b (18.5%)	11.0±4.6c (55.8%)
Total	43	42	33
	24.0±5.6a	20.6±4.4b (14.2%)	10.3±3.1c (57.1%)

Values in the same row with the same letter present a significance level of $P>0.05$. (a) fresh basis. (b) dry basis.
[a] Number of samples.
[b] Average±standard deviation.

Acknowledgements

This work was financed in part by the Union European, Project UE-FEDER/DGSIC, Reference 1FD97-1138. We wish to express our gratitude to the Exmo. Cabildo Insular de Tenerife for a grant for Ricardo Casañas to carry out the experimental works. Also, the authors gratefully acknowledge MERCATENERIFE and CULTESA for providing potato samples.

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