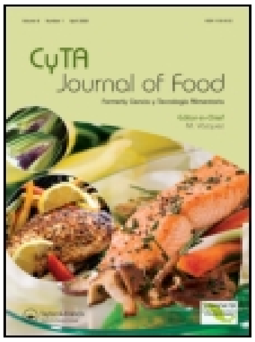

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Influencia de las condiciones de almacenamiento sobre las características sensoriales y físicoquímicas de patatas Kennebec de Galicia (*Solanum tuberosum* L.)

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In this study, we compared conventional storage of Kennebec potatoes in a ventilated room at ambient temperature with storage at controlled temperatures of 10, 7 and (initially) 4°C as regards the evolution of colour, hardness, dry matter, pH, vitamin C and sugar contents and sensory properties. The increase in sugar content in potatoes stored at 4°C was so rapid that within 15 days their reducing sugar content exceeded the permitted limit for sale under the EU Protected Geographical Indication label "Pataca de Galicia". Sugar content also increased at 10 and 7°C, but after 3 months the increase was not sufficient to exceed the specified limit. The sugar content of conventionally stored potatoes remained approximately constant, but these potatoes became softer, flabbier and more wrinkled due to loss of moisture. Overall, storage at 7°C seemed to be the best of the storage conditions tested.

Keywords: potato; storage; sensory analysis; physicochemical analysis

El objetivo de este estudio es evaluar los cambios que se producen en patatas almacenadas a lo largo del tiempo en condiciones controladas a temperaturas de 10 y 7 e, inicialmente, 4°C, frente a la condición normal de almacenamiento de la patata en almacenes ventilados. Las muestras fueron analizadas desde el punto de vista físico-químico (color CIEL*a*b* (1976), dureza, materia seca, pH, azúcares y vitamina C) y sensorial (QDA). El aumento del contenido en azúcares y, por tanto, del sabor dulce en las patatas almacenadas a 4°C fue tan rápido que el plazo de 15 días el contenido de azúcares superó el límite permitido para patatas amparadas bajo la Indicación Geográfica Protegida de la Unión Europea "Pataca de Galicia". El contenido en azúcares también aumentó en las patatas almacenadas a 10 y 7°C, si bien, después de tres meses, el aumento no fue suficiente para superar el límite especificado. El contenido de azúcares de las patatas almacenadas convencionalmente se mantuvo constante, pero se produjo una pérdida de firmeza sensorial y dureza instrumental y un incremento de la rugosidad de la piel debido a la pérdida de humedad. En general, el almacenamiento a 7°C parece ser la mejor de las condiciones de almacenamiento ensayadas.

Palabras clave: patata; almacenamiento; análisis sensorial; análisis fisico-químico

Introduction

Unlike leaf or fruit vegetables (lettuce, runner beans, tomatoes, etc.), potatoes and other tubers can be stored unfrozen for months. However, the persistence of metabolic processes during storage leads to chemical changes that affect – usually though not necessarily unfavourably – organoleptic properties and other quality variables (Cinar, 2004; Diehl & Hamann, 1979; Jindal & Techasena, 1986; Laza, Scanlon, & Mazza, 2001; Ridley & Lindsay, 1984; van Oirschot, Rees, & Aked, 2003). The extent of these changes depends on the storage conditions (Nourian, Ramaswamy, & Kushalappa, 2003b; Pardo, Alvarruiz, Perez, Gomez, & Varon, 2000), especially temperature, relative humidity and exposure to light (Laza et al., 2001).

For potatoes, darkness is virtually an absolute requirement, because light induces the synthesis of the toxic alkaloid solanine (as well as chlorophyll, which makes stored potatoes turn green). Relative humidity should be high to prevent desiccation (Belitz & Grosch, 2004). Temperature can influence colour and texture (Alvarez & Canet, 2000; Laza et al., 2001; Nourian, Ramaswamy, & Kushalappa, 2003a), mainly through its effect on respiration. Temperatures below 5°C inhibit respiration, but continued hydrolysis of starch leads to the accumulation of reducing sugars, to the detriment of colour, flavour and texture (Blenkinsop, Copp, Yada, & Marangoni, 2002; Chourasia & Goswami, 2001; Davids, Varoujan, Yaylayan, & Turcotte, 2004) and of the response to cooking. Temperatures above 21°C increase respiration and prevent the accumulation of reducing sugars but cause spoilage (Cheftel & Cheftel, 1992).

In view of the above, it is desirable to optimize storage conditions so as to maximize the time for which potatoes can be stored without loss of quality. Though the ultimate criteria of quality are sensorial, mechanical and physicochemical parameters that are appropriately correlated with sensory qualities, whether, through causal relationships or otherwise, can be employed as rapidly applicable objective surrogates (Povlsen; Rinnan, van den Berg, Andersen, & Thybo, 2003;

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Solomon & Jindal, 2007; Thybo, Christiansen, Kaack, & Petersen, 2006; Thybo & Martens, 1999; Ulrich, Hoberg, Neugebauer, Tiemann, & Darsow, 2000; van Marle, DeVries, Wilkinson, & Yuksel, 1997).

Galicia (NW Spain) is one of Spain's major potato-growing regions. The most widely grown cultivar is the high-quality, high-value Kennebec potato, the only cultivar eligible for sale under the EU Protected Geographical Indication label "Pataca de Galicia". In the main part of the study described here, Galician Kennebec potatoes stored under three distinct sets of conditions (conventional storage at ambient temperature in a ventilated room; storage at 7°C and storage at 10°C) were sampled periodically over a 3-month period, and uncooked and boiled samples were evaluated physicochemically and sensorially on each occasion. In addition, potatoes stored at 4°C for 15 days were evaluated sensorially to verify that the resulting increase in reducing sugars was sufficient to affect sweetness.

Material and methods

Samples

Potatoes (*Solanum tuberosum* L., cv. Kennebec) were supplied by an authorized wholesaler. A random sample was taken, and the remainder was divided in four lots (each lot was composed of 100 kg of potatoes). Three lots were stored in the dark in chambers maintained at a relative humidity of 85% and temperatures of 4, 7 and 10°C, and the fourth was stored in the dark in a room with conventional ventilation (during the study period, the temperature of this room was 14.1 $\pm$ 0.3°C and its relative humidity was 75.8 $\pm$ 11.1%). Over the following 3 months, random samples were taken at intervals of between 8 and 15 days from each lot except that stored at 4°C; this latter lot was sampled on day 15 and, in the light of the results obtained at that time (see below), was then discarded.

Prior to evaluation, some of the potatoes of each sample were peeled and boiled whole for 50 min in distilled water at a potato/water ratio of 1 kg to 1.5 L. No salt was added, potatoes from different samples were boiled in different pots, and the pots were heated on a 2-kW hotplate. All boiled potatoes were allowed to cool to room temperature before analysis, and potatoes destined for sensory analysis were cut into four.

Sensory analysis

Sensory analysis was carried out by eight panellists trained and selected for potato evaluation as described elsewhere (Montouto-Graña, Fernández-Fernández, Vázquez-Odériz, & Romero-Rodríguez, 2002).

On the first post-storage sampling occasion (day 15), prior to the construction of sensory profiles, the boiled potatoes from the ambient-temperature, 10°C, 7°C and 4°C samples were subjected to similarity analysis (McCullough, Martinse, & Moinpour, 1978): the six possible pairs of samples were scored on a 10-cm unmarked scale labelled "Exactly the same" at one end and "Completely different" at the other. Once the existence of between-lot dissimilarity had been verified, sensory profiles were constructed for all four lots as described below.

Sensory profiles were constructed using a modified version of the protocol described elsewhere (Montouto-Graña et al., 2002). Briefly, each panellist first evaluated the colour, roughness and wrinkling of the skin of raw potatoes of each sample before cutting them into half to evaluate aroma intensity, moistness, internal colour and firmness. The panellist then evaluated the boiled potatoes for internal colour, aroma intensity, moistness-in-the-mouth, pastiness, chewiness, sweetness, flavour intensity and after-taste persistence. In all cases, the different descriptors were quantified using 10-cm non-structured intensity scales. These evaluations were performed in accordance with a randomized complete block experimental design: two duplicate samples of both boiled and raw potatoes from each lot were identified with three-digit numbers and presented to each panellist in random order.

Physicochemical analysis

With the exceptions of hardness and skin colour, all the physicochemical variables considered were determined for both uncooked and boiled potatoes, using at least 10 potatoes per storage condition.

The CIELab colours (CIE, 1976) of skin and flesh were determined using an X-Rite 968 reflection spectrophotometer (X-Rite, Grand Rapids, MI, USA) as described by Artigas, Gil, and Felipe (1985). For both uncooked and boiled potatoes, flesh colour was determined as the mean of three measurements, one in the centre and two near the periphery.

The hardness of uncooked potatoes was measured with a penetrometer (Bertuzzi FT-327, Facchini, Italia), with a 8-mm plunger, respectively. After removal of a small area of skin, the penetrometer plunger was placed perpendicular to the uncovered surface of the flesh, increasing pressure was applied, and the pressure at which the plunger tip entered the potato was recorded (Ranganna, 1986).

Dry matter was determined following desiccation for 4 h at 100 $\pm$ 2°C (AOAC, 2000), pH with an automatic pH-meter (AOAC, 2000), vitamin C by Jasco HPLC, which, for this analysis, was equipped with a Spherisorb ODS2 C18 column (250 $\times$ 4.6 mm, 5 μm) and a Spherisorb ODS2 C18 precolumn (10 $\times$ 4.6 mm, 5 μm) thermostated at 25°C; the mobile phase was a 0.4 mL/min flow of Milli-Q water acidified to pH 2.2 with sulphuric acid and the detection wavelength was 245 nm (Romero-Rodríguez, Vázquez-Odériz, López-Hernández, & Simal-Lozano, 1992), and sugars (glucose, fructose and sucrose) using an enzymatic assay (Ref. 0716260) from Boehringer-Mannheim Roche (F. Hoffmann-La Roche Ltd, Basel, Switzerland).

Statistical analyses

For day 15, samples were subjected to proximity analysis with data obtained in the similarity analysis. Sensory and physicochemical variables to one-way analyses of variance (ANOVAs) were followed by planned comparisons of the results for the 4°C sample with the others. Additionally, the 4°C sample was compared with the pre-storage sample using Student's *t* test. What follows refers to the analyses of results for all samples from lots stored at ambient temperature, 7°C and 10°C.

The data for each physicochemical variable were analysed by ANOVA of a split-plot model with storage condition as whole-plot factor and sampling time as subplot factor:

$$Y_{ijk} = \mu + \alpha_i + \delta_{ik} + \beta_j + \alpha\beta_{ij} + \varepsilon_{ijk}$$

where μ is the grand mean, α_i the effect of the ith storage condition, δ_{ik} the within-storage-condition random error, β_j the effect of the jth storage time, $\alpha\beta_{ij}$ the interaction effect between storage time and storage condition and ε_{ijk} is the random measurement error. The data for sensory variables were analysed by ANOVA of a randomized complete block model with storage condition and storage time as factors and panellist as block:

$$Y_{ijkr} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \varepsilon_{ijkr}$$

where μ is the grand mean; α_i, β_j and γ_k are the effects of the ith storage condition, the jth storage time and the kth panellist, respectively; $\alpha\beta_{ij}$ is the interaction effect between storage time and storage condition and ε_{ijkr} is the random evaluation error. In the case of physicochemical colour data, these analyses were performed on the factors identified by factor analysis of the CIELab colour descriptors. Also, for both physicochemical and sensory results, *post hoc* comparisons were performed using Tukey's test, and, for physicochemical results, time-trends were examined by polynomial contrasts (results not shown).

Finally, variables for which significant differences among storage conditions had been detected were subjected to generalized procrustean analyses (one for physicochemical variables except sugar contents, one for selected sensory characteristics, sugar contents, hardness and post-boiling CIELab colour variables).

All statistical calculations were performed using either SPSS v.14.0 for Windows (SPSS Inc., Chicago, IL, USA) or the Excel statistical package XLSTAT (Addinsoft, Barcelona, Spain).

Results and discussion

Preliminary study

Proximity analysis of the similarity data for samples taken on day 15 afforded a model explaining 93% of the variance that showed dissimilarity between the 4°C sample and the others. One-way ANOVA showed significant differences among storage conditions in regard to sensory sweetness ($F = 7.558$, $p = 0.001$), and a subsequent planned comparison confirmed the significance of the difference between the 4°C sample (mean sweetness 6.9) and the others (each with mean sweetness $\approx$3.0). Similarly, ANOVAs showed significant between-storage-condition differences in glucose, fructose and sucrose contents ($F = 23{,}566.19$, $p < 0.001$; $F = 26{,}133.83$, $p < 0.001$ and $F = 59.89$, $p = 0.001$, respectively) that were likewise confirmed due to the high contents of the 4°C sample, which had a mean glucose content of 4.5 g/kg fresh weight, a mean fructose content of 4.6 g/kg fresh weight and a mean sucrose content of 1.5 g/kg fresh weight. The sum of glucose and fructose of this sample was more than double the content permitted (4.0 g/kg fresh weigh) by the legislation governing the Protected Geographical Indication "Pataca de Galicia" (Orden de 29 de octubre de 2001).

Student's t tests of the differences between the 4°C sample and the pre-storage sample showed that storage was associated with significant increases in the mean values of sensory sweetness, glucose (originally 0.2 g/kg fresh weight), fructose (originally 0.2 g/kg fresh weight), sucrose (originally 0.5 g/kg fresh weight), sensory colour [which increased from 2.9 (whitish) to 5.4 (yellowish)], CIELab b^* (increased yellowness) and CIELab C^* (increased chroma).

Increased sweetness and slight darkening of potatoes as the result of low-temperature storage have previously been reported by Kazami, Tsuchiya, Kobayashi, and Ogura (2000) and Davids et al. (2004). The darkening is very possibly due to a higher level of non-enzymatic browning activity due to the increase in reducing sugars, which occurs more rapidly at 4°C than at higher temperatures (Nourian et al., 2003b). Although a sweet-tasting potato is not necessarily objectionable, it is not the type that is aimed at and protected by the "Pataca de Galicia" label, which as noted above requires a glucose plus fructose concentration lower than 4.0 g/kg fresh weight.

In view of the above, storage at 4°C was discarded as a possible optimal storage regime, and only the lots stored under other conditions were studied for longer than 15 days.

Final study

Tables 1 and 2 summarize the results of ANOVAs of the influence of storage condition and storage time on their various sensory and physicochemical characteristics.

The only sensory variable for which storage time definitely had a significant effect that was consistent among storage conditions was the chewiness of the boiled potato, which decreased with increasing storage time. Storage condition had significant effects on uncooked-potato firmness and boiled-potato moistness-in-the-mouth and an effect on uncooked-potato roughness that was of borderline statistical significance. For uncooked-potato wrinkling and boiled-potato aroma intensity, both the main effect of storage condition and the cross-effect (storage condition × time) were statistically significant. Tukey's test failed to identify significant pairwise between-lot differences in roughness and

Table 1. Statistical significance (p values) of the individual and cross-effects of storage condition and storage time on sensory properties of uncooked and boiled Galician Kennebec potatoes, as indicated by ANOVA as described in the "Material and methods" section.

Tabla 1. Resultados del ANOVA (p valor) de dos factores (condición de almacenamiento y tiempo de almacenamiento) y de la interacción de ambos sobre las características sensoriales de patatas Kennebec de Galicia crudas y cocidas.

Characteristic	Condition	Time	Cond. × time
Uncooked potatoes			
Skin colour	0.724	0.865	0.199
Wrinkling	<0.001	0.278	0.034
Roughness	0.044	0.537	0.413
Aroma intensity	0.897	0.418	0.307
Moistness	0.186	0.158	0.481
Internal colour	0.390	0.180	0.716
Firmness	<0.001	0.058	0.135
Boiled potatoes			
Internal colour	0.162	0.080	0.282
Aroma intensity	0.005	0.490	0.019
Moistness-in-the-mouth	0.021	0.059	0.076
Pastiness	0.341	0.231	0.367
Chewiness	0.729	0.018	0.769
Sweetness	0.727	0.070	0.817
Flavour intensity	0.643	0.458	0.114
Aftertaste persistence	0.423	0.401	0.557

Table 2. Statistical significance (p values[a]) of the individual and cross-effects of storage condition and storage time on physicochemical properties of uncooked and boiled Galician Kennebec potatoes, as indicated by ANOVA as described in the "Material and methods" section.

Tabla 2. Resultados del ANOVA (p valor) de dos factores (condición de almacenamiento y tiempo de almacenamiento) y de la interacción de ambos sobre las características físico-químicas de patatas Kennebec de Galicia crudas y cocidas.

	Uncooked			Boiled		
Characteristic	Condition	Time	Cond. × time	Condition	Time	Cond. × time
Hardness	0.033	<0.001	0.122			
pH	0.235	<0.001	0.231	0.252	<0.001	0.051
Dry matter	0.031	0.054	<0.001	0.085	0.267	0.001
Vitamin C	0.031	<0.001	0.001	0.937	0.255	0.051
Flesh colour[b]	0.125	0.010	0.020	0.409	0.826	0.059
Skin colour[b]	0.016	<0.001	<0.001			
L^*-related factor[b]	0.606	0.686	0.861	0.897	0.002	0.195
Glucose	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Fructose	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sucrose	0.001	<0.001	<0.001	0.001	<0.001	<0.001

Notes: [a]For data with significant Mauchy sphericity ($p < 0.05$), F tests were performed following Huynh–Feldt correction of the degrees of freedom. [b]Factors obtained by the factor analysis are summarized in Table 3.

moistness-in-the-mouth, but firmness was significantly greater at low temperatures (means of 5.3 at 10°C and 5.8 at 7°C) than under conventional storage conditions (mean 2.4); lack of firmness has been pointed out as a cause of rejection by consumers (Nourian et al., 2003b). The behaviour of the conventionally stored lot was also largely responsible for the differences in wrinkling (mean 7.9 in this lot, 4.6 at 10°C and 4.2 at 7°C) and in boiled-potato aroma intensity (mean 4.4 at ambient temperature, 5.6 at 10°C and 5.5 at 7°C), and the changes in these effects with increasing storage time gave rise to significant interaction in the ANOVA. The great differences in wrinkling and firmness between the conventionally stored lot and the others are illustrated by graphic display of the sensory profile afforded by the five variables that differed among storage conditions (Figure 1). Neither storage condition nor storage time had significant effects on the sensory colour of either uncooked or boiled potatoes.

The differences in wrinkling and sensory firmness noted above are attributable to the increased dry matter and decreased hardness (measured with the penetrometer) of the conventionally stored lot. Dry matter hardly changed during storage at 7°C and only increased transitorily at 10°C, but, at ambient temperature, it increased considerably towards the end of the 3-month storage period, giving rise to a statistically significant interaction between storage condition and storage time. Potatoes also became softer towards the end of the storage period and, on average, offered less resistance to penetration when stored conventionally (8.74 kg) than when stored at 10°C (9.79 kg) or 7°C (9.20 kg). The markedly increased dry matter content and greater softness of conventionally stored potatoes (and through these variables their increased wrinkling and lesser sensory firmness) are attributable to the variability and relatively low mean value of the relative humidity of the conventional storage room, high relative humidity being required to prevent loss of moisture (Laza et al., 2001).

On average, the skin of conventionally stored potatoes had slightly larger values of CIELab a^* (8.3), b^* (23.5) and C^* (25.0) than that of potatoes stored at 10°C (a^*, 7.8; b^*, 21.9 and C^*, 23.3) or 7°C (a^*, 7.5; b^*, 21.3 and C^*, 22.6), and also a larger difference ΔE with respect to colour at time zero (6.3, as against 4.2 at 10°C and 3.5 at 7°C). These differences, which were like the changes in dry matter and hardness (measured with the penetrometer), were probably due to lower ambient relative humidity and were reflected in the values of these lots on the second of the three factors identified by factor analysis of the CIELab colour data, which together accounted for 72.2% of the variance among uncooked potatoes (Table 3). Accordingly, in the corresponding ANOVA (Table 2), this skin-colour factor showed a significant storage condition effect in addition to the storage time effect and interaction effect. For the first factor to emerge from the factor analysis, which aggregated flesh colour variables, only the storage time effect and cross-effect were statistically significant. For the third factor, which was dominated by CIELab L^* for flesh and skin, neither storage time nor storage condition were associated with statistically significant variation, but it may nevertheless be noted that samples from the conventionally stored lot always had negative values of this factor, while samples of the other two lots always had positive values.

The vitamin C content of uncooked potatoes was unaffected by storage at 7°C but changed significantly with increasing storage time in the other lots, giving rise to a significant storage condition effect and a significant storage condition × time effect in the ANOVA. On average, vitamin C content was 31.0 mg/kg fresh weight at 7°C, 28.0 mg/kg fresh weight at 10°C and 25.0 mg/kg fresh weight at ambient temperature. The lower vitamin C content of the conventionally stored potatoes is probably attributable to the higher storage temperature. Loss of vitamin C is associated with altered colour and reduces nutritional value (Nourian et al., 2003b).

The pH of uncooked potatoes rose significantly whatever their storage conditions, without significant differences among lots. This behaviour differs from that reported by Nourian et al. (2003b) for Chieftain potatoes, the pH of which decreased during storage and decreased more rapidly at higher temperatures than lower.

Boiled potatoes showed no significant effects of either storage time or storage conditions on vitamin C content. The effect of storage time on their pH was statistically significant, but it was negligible in practical terms, all the values measured lying in the range pH 5.97–6.15. The behaviour of the dry matter contents of boiled potatoes paralleled that

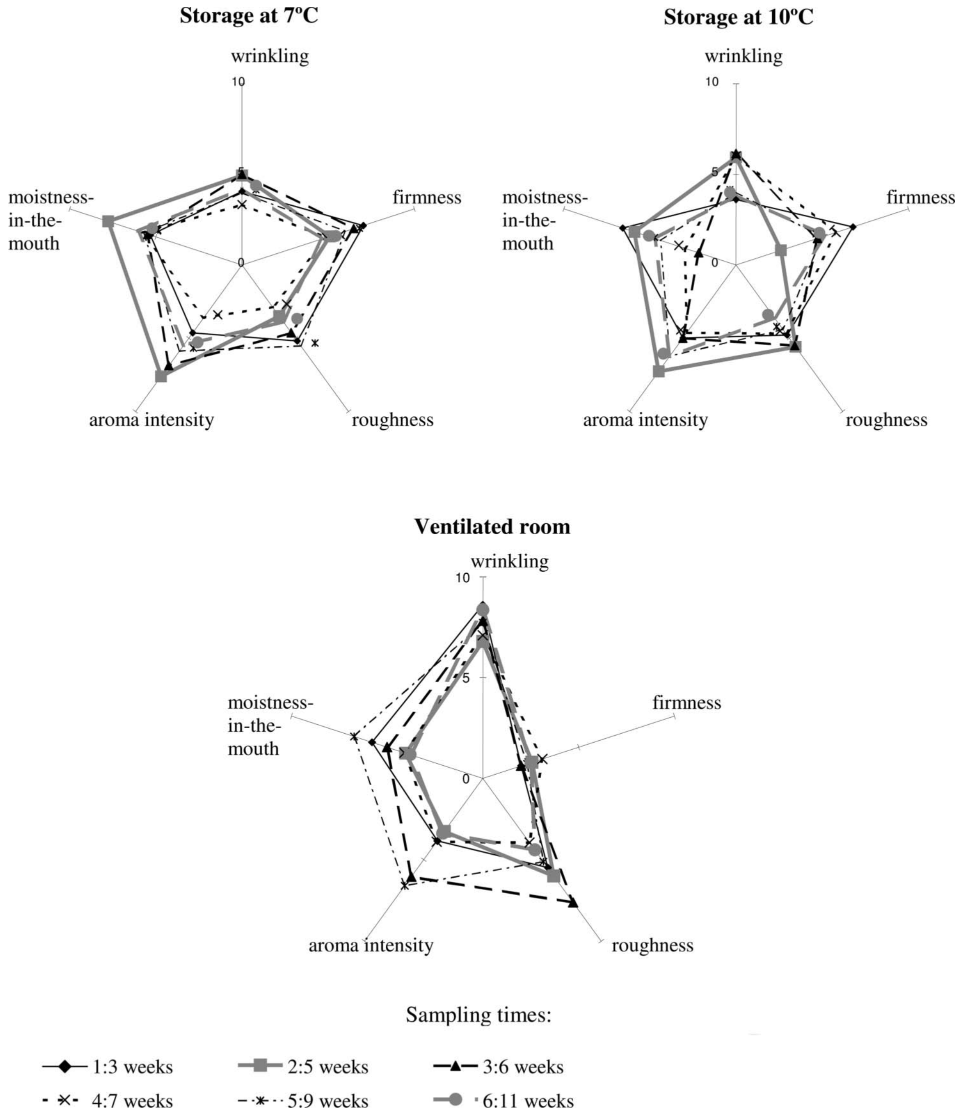

Figure 1. Sensory profiles of Galician Kennebec potatoes after various periods of storage in a ventilated room or at temperatures of 7 or 10°C.

Figura 1. Perfil sensorial de las patatas Kennebec de Galicia después de varios periodos de almacenamiento en un almacén ventilado y a temperaturas de 7 y 10°C.

Table 3. Factor loadings and variance accounted for by the factors identified by factor analysis of the CIELab colour data (only factor loadings greater than 0.4 are shown).

Tabla 3. Cargas factoriales y porcentaje de varianza explicado por los factores en el análisis factorial aplicado a los datos de color CIELab (sólo se muestran los valores superiores a 0,4).

	Uncooked			Boiled	
	Factor F1 (flesh colour)	Factor F2 (skin colour)	Factor F3 (L^* related)	Factor F1 (flesh colour)	Factor F2 (L^* related)
a^* (flesh)	0.898			−0.823	
b^* (flesh)	−0.869			0.914	
C^* (flesh)	0.779		0.431	0.813	0.522
h^* (flesh)	0.758		0.440	0.973	
ΔE (flesh)[a]	0.634		−0.405		0.498
a^* (skin)		0.939			
b^* (skin)		0.917			
C^* (skin)		0.873			
h^* (skin)		−0.417			
L^* (skin)			0.653		
L^* (flesh)			0.842		0.908
Variance accounted for	29.5%	26.8%	15.9%	52.6%	27.4%
Total variance accounted for		72.2%		80.0%	

Note: [a]Relative to the value at time zero.

of their uncooked dry matter contents. Factor analysis of the CIELab colour data for boiled potatoes produced two factors accounting for 80% of the total variance, the first factor being associated with chromatic variables (a^*, b^*, C^* and h^*) and the second depending mainly on L^* (Table 3). The first factor was not significantly affected by either storage condition or storage time (Table 2), although potatoes stored conventionally and at low temperature had average values of this factor of opposite signs (as in the case of the L^*-related factor of uncooked potatoes), the average value being positive for conventionally stored potatoes and negative for both the other two conditions. The value of the lightness-

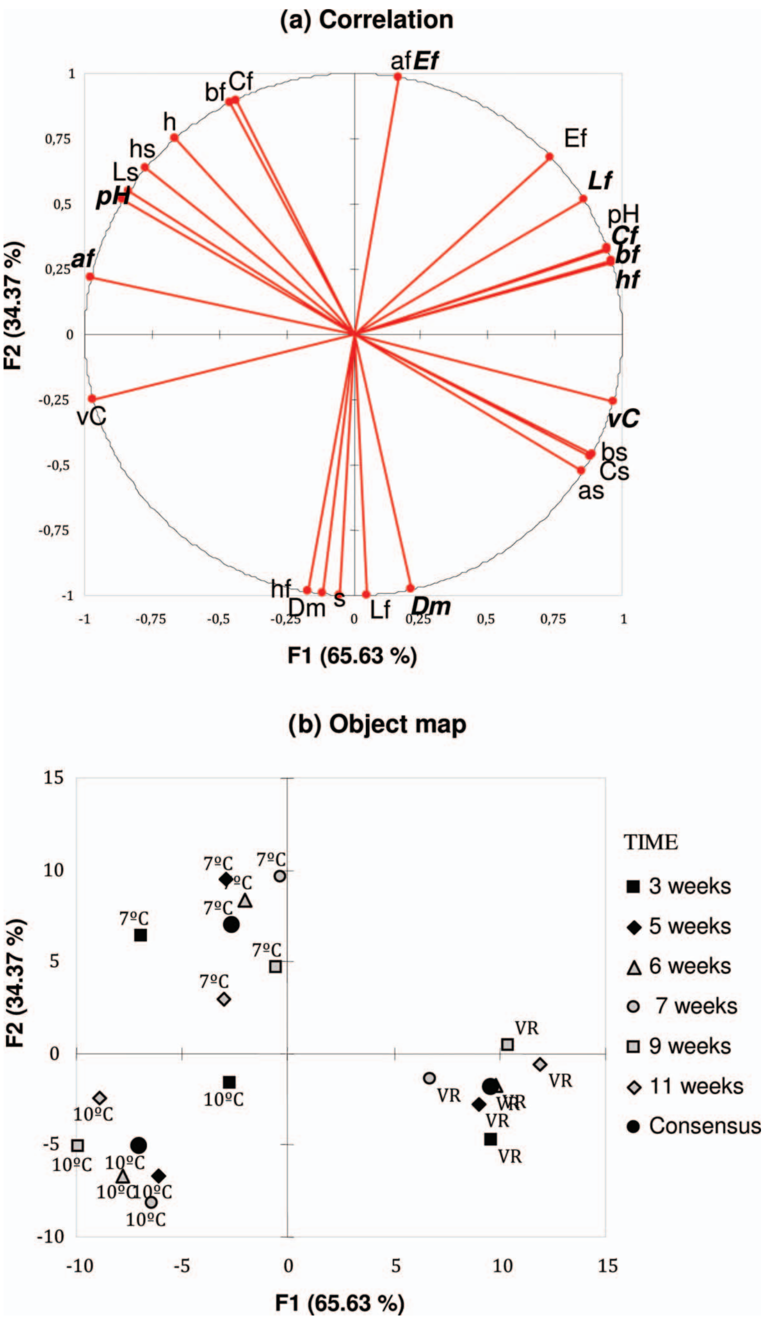

Figure 2. Results of generalized procrustean analysis of the behaviour of the physicochemical characteristics of the potatoes other than their sugar contents. (a) Graphic of correlations between physicochemical variables and the factors identified by principal component analysis of the consensus configuration. (b) Object map. Nomenclature (bold type indicates variables for boiled potatoes): *s*, size; *h*, hardness; pH; dm, dry matter; vC, vitamin C; Lf, L^* (flesh); af, a^* (flesh); bf, b^* (flesh); Cf, C^* (flesh); hf, h^* (flesh); Ef, ΔE (flesh); Ls, L^* (skin); as, a^* (skin); bs, b^* (skin); Cs, C^* (skin); hs, h^* (skin).

Figura 2. Resultados del análisis procruster generalizado sobre las características físico-químicas, excepto contenido en azúcares, de patatas. (a) Gráfico de correlaciones entre las variables físico-químicas y los factores identificados por el análisis de componentes principales. (b) Gráfico de puntuaciones. Nomenclatura (letras en negrita indica variables para patatas cocidas): *s*, tamaño; *h*, dureza; pH; dm, materia seca; vC, vitamina C; Lf, L^* (pulpa); af, a^* (pulpa); bf, b^* (pulpa); Cf, C^* (pulpa); hf, h^* (pulpa); Ef, ΔE (pulpa); Ls, L^* (piel); as, a^* (piel); bs, b^* (piel); Cs, C^* (piel); hs, h^* (piel).

related factor fell with increasing storage time regardless of storage condition, which had no influence on this variable (Table 2).

The behaviour of the physicochemical characteristics of the potatoes other than their sugar contents is summarized in Figure 2, which shows the results of a generalized procrustean analysis in which each sampling time was treated as a configuration. The factor loading chart [Figure 2(a)] shows that the first factor identified by principal component analysis of the consensus configuration is defined largely by vitamin C contents, pH and the CIELab colour variables of boiled potatoes and of the skin of uncooked potatoes; while

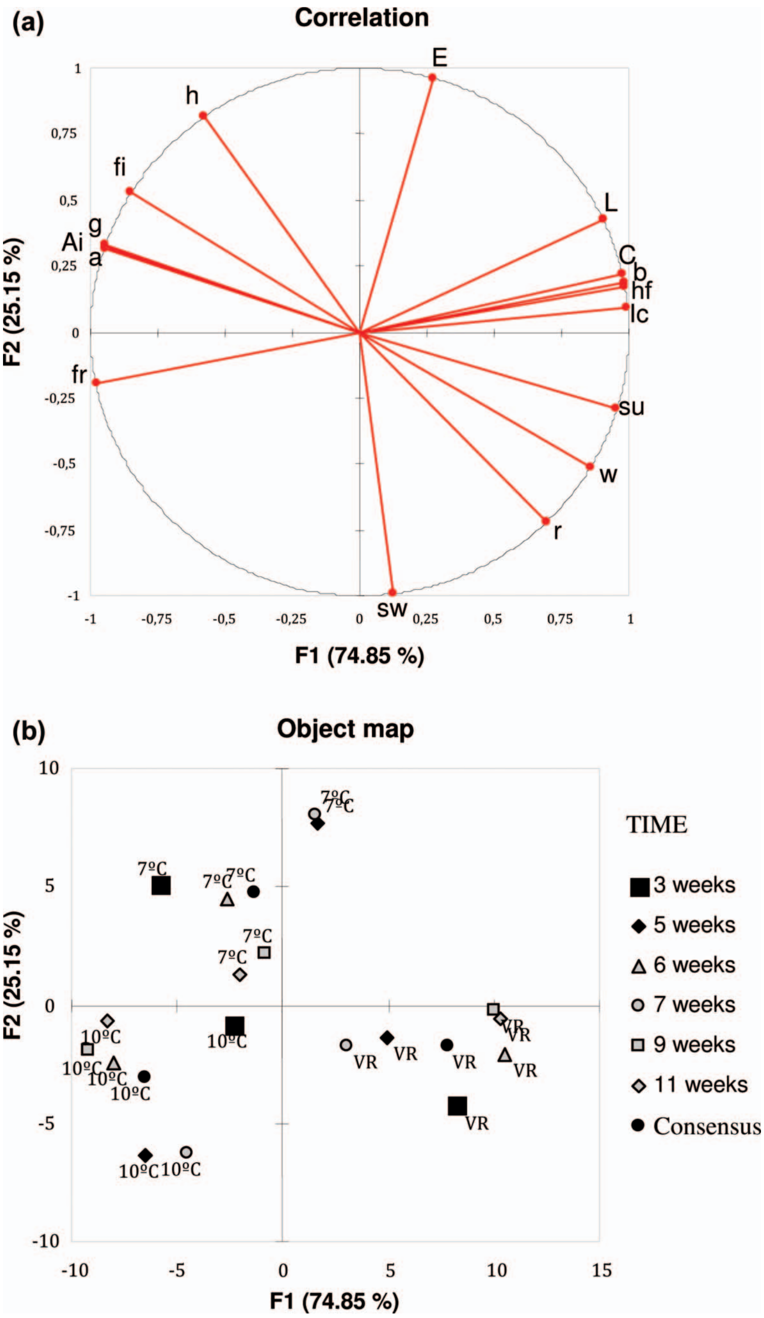

Figure 3. Results of generalized procrustean analysis of the behaviour of selected sensory characteristics, sugar contents, hardness and post-boiling CIELab colour variables. (a) Chart of correlations between the variables considered and the factors identified by principal component analysis of the consensus configuration. (b) Object map. Nomenclature: *w*, wrinkling; *r*, roughness; fi, firmness; Ic, internal colour (boiled potatoes); Ai, aroma intensity (boiled potatoes); sw, sweetness; *h*, hardness; *L*, *L** (flesh); *a*, *a** (flesh); *b*, *b** (flesh); *C*, *C** (flesh); *hf*, *h** (flesh); *E*, Δ*E* (flesh); *g*, glucose; fr, fructose; su, sucrose.

Figura 3. Resultados del análisis procuster generalizado de las características sensoriales, el contenido en azúcares, la dureza y el color CIELab tras la cocción. (a) Gráfico de correlaciones entre las variables consideradas y los factores identificados por el análisis de componentes principales. (b) Gráfico de puntuaciones. Nomenclatura: *w*, rugosidad; *r*, aspereza; fi, firmeza; Ic, color interno (patatas cocidas); Ai, intensidad del aroma (patatas cocidas); sw, sabor dulce; *h*, dureza; *L*, *L** (pulpa); *a*, *a** (pulpa); *b*, *b** (pulpa); *C*, *C** (pulpa); *hf*, *h** (pulpa); *E*, Δ*E* (pulpa); *g*, glucosa; fr, fructosa; su, sacarosa.

the second factor is defined largely by the dry matter content of uncooked potatoes and the CIELab colour variables of their flesh. The object map [Figure 2(b)] highlights the differences among the three storage conditions in these respects. Conventional storage afforded values at the positive extreme of factor F1, cooked potatoes having yellower flesh and higher vitamin C contents under these conditions than at low temperature, and uncooked potatoes higher skin chroma and pH and lower vitamin C content and hardness (measured with the penetrometer). Though accounting for less variance, factor F2 separated potatoes stored at 7°C from the others: storage at 7°C afforded higher F2 values indicative of less dry matter content and a greater flesh colour difference, with respect to pre-storage potatoes.

ANOVAs of the sugar contents of both uncooked and boiled potatoes showed very significant cross-effects between storage condition and storage time (Table 2). The sucrose content of conventionally stored potatoes increased with storage time and was higher than that of those stored in cool chambers. By contrast, the glucose and fructose contents of conventionally stored uncooked potatoes remained fairly unchanged, with averages over time of 0.16 g/kg fresh weight and 0.09 g/kg fresh weight, respectively, whereas those of the other lots fluctuated more widely and on average were higher, although the sum of the average glucose and fructose contents (1.3 g/kg fresh weight at 7°C and 2.0 g/kg fresh weight at 10°C) did not exceed the upper limit permitted by the legislation governing the Protected Geographical Indication "Pataca de Galicia", 4.0 g/kg fresh weight. Nourian et al. (2003b) observed that reducing sugar content increased with increasing storage time and decreasing temperature.

Boiled potatoes should be creamy white, with a moderately dry and mealy texture, and have a natural potato aroma (Nourian et al., 2003a). Consumers tend to reject potatoes that are flabby, oversweet or show anomalous coloration (Nourian et al., 2003b). Figure 3 shows the results of a generalized procrustean analysis that included selected sensory characteristics (the wrinkling, roughness and firmness of uncooked potatoes, and aroma intensity, colour and sweetness when boiled) together with sugar contents, hardness (measured with the penetrometer) and post-boiling CIELab colour variables; as in the analysis of Figure 2, each configuration consisted of the data obtained at a given sampling time. Once more, conventionally stored potatoes cluster at the positive end of the first factor extracted by principal component analysis of the consensus configuration, and potatoes stored at 7°C have larger F2 values than the others. Conventionally stored potatoes are clearly separated from potatoes stored in the cool, largely because they had lower reducing sugar contents and were flabbier, softer, rougher, more wrinkled and more highly coloured when boiled.

Conclusions

The changes in quality characteristics caused by the storage of Galician Kennebec potatoes depend upon storage conditions. The quality of potatoes is maintained better at a relative humidity of 85% and a temperature of 7°C or 10°C (especially the former) than under conventional storage in a ventilated room, which facilitates loss of hardness (measured with the penetrometer), loss of sensory firmness and increased wrinkling due to loss of moisture. The increase in sugar content and sweetness in potatoes stored at 4°C is so rapid that within 15 days it makes them ineligible for protection under the Protected Geographical Indication label "Pataca de Galicia". These findings suggest that efforts should be made to ensure that potatoes sold under the "Pataca de Galicia" label are stored under conditions that maintain their quality throughout storage.

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