ELSEVIER

0308-8146(95)00159-X

Food Chemistry, Vol. 56, No. 2, pp. 163–166, 1996

0308-8146/96 $15.00+.00

Changes in soluble sugars of two pineapple fruit cultivars during frozen storage

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(Received 17 June 1995; revised version received and accepted 11 July 1995)

Sugar changes taking place during freezing and frozen storage of two pineapple fruit cultivars, Smooth Cayenne and Red Spanish, were studied. Pineapple fruit was frozen as slices in a cold room at −18°C and stored at this temperature for a 12-month period. The sugar content was measured by high-performance liquid chromatography (HPLC) and compared to the total soluble solids determined by refractive index. Both were linearly related. HPLC identified the major components as fructose, glucose and sucrose. A high correlation was observed between the different sugars in the two cultivars during frozen storage. Freezing preservation of pineapple fruit slices led to minimal changes in soluble solids and sugar content (fructose, glucose and sucrose) after 1 year of frozen storage.

INTRODUCTION

Pineapple fruit (*Ananas comosus* L., Merrill) is widely used as an important constituent in a nutritious diet. Among the principal varieties are Smooth Cayenne and Red Spanish. The range of chemical constituents of ripe pineapple, depending upon stage of fruit ripeness, and agronomic and environmental factors, has been reported by Dull (1971), Flath (1980) and Kermasha *et al.* (1987). The pineapple fruit sold at the local markets in Spain is cultivar Smooth Cayenne of tropical origin (Ivory Coast mainly). In the past few years, pineapple fruit culture was introduced into one of the Canary Islands (Hierro, Spain). Some different cultivars were tried, but nowadays only cv. Red Spanish is grown.

Pineapple fruit is preserved by freezing to a limited extent. Cultivar Smooth Cayenne, grown in Hawaii, Puerto Rico and other tropical regions is the principal cultivar used for freezing (Luh *et al.*, 1986).

The sugar composition of pineapple plays an important role in its perceived quality and consumer acceptability. Sugar content is affected not only by weather conditions, but also by fruit conditions. Pineapple juice has a similar composition to that of the fruit from which it is obtained. Storing commercial pineapple juice at −15°C for at least 18 months did not introduce changes in the total sugar contents or individual sugar contents as analysed with a total sugar analyser and by gas–liquid chromatography (GLC) (Li & Schuhmann, 1983). The sugar content of pineapple fruit is affected by the fruit variety (Hodgson & Hodgson, 1993). Nayar *et al.* (1981) reported a different trend of sugar values for the same varieties. These variations are expected even within the same sub-varieties, since other factors, such as growing conditions, practice and postharvest handling, affect the quality of the fruit.

The objective of this study was to evaluate the influence of the freezing process and frozen storage on the sugar content in two pineapple fruit cultivars (Smooth Cayenne and Red Spanish).

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MATERIALS AND METHODS

Pineapple fruit (*Ananas comosus*, L.) cultivars Red Spanish and Smooth Cayenne, from Canary Island and Ivory Coast, respectively, were obtained from commercial sources. Fruits were stored at 8±1°C and 80–90% relative humidity (Cancel, 1974; Bartolomew & Paull, 1986) until they reached the proper maturity level for processing (12.5°Brix for cv. Smooth Cayenne and 10.3°Brix for cv. Red Spanish).

Processing

Firm ripe fruits were hand-peeled, cored, sliced (1.0±0.2 cm) and cut into small pieces. Pineapple fruit slices were packed in plastic bags (Polyskin X, 12 μm thick), containing 390±10 g fruit, sealed, frozen in a cold room at −18°C and stored at this temperature for 12 months.

Product analyses

Samples were evaluated before freezing, after freezing and after storage at −18°C for 1, 2, 4, 6, 8 and 12 months. Two bags of pineapple fruit slices were removed from frozen storage and thawed under controlled conditions (placed at room temperature, 20°C, for 3 h prior to immediate analysis). Analysis values reported for each cultivar at each sampling interval reflect the mean of all measurements (at least three).

Soluble solids

The soluble solids of the slices were determined with a digital refractometer (Atago dbx-30, Tokyo). The results were reported as °Brix 20°C.

Sugars

The most important carbohydrates in pineapple fruit (sucrose, fructose and glucose) were analysed by HPLC (Bartolomé, 1992) using a Hewlett-Packard model 1040 instrument with a Refractive Index detector model 1047A, employing a Sugar Pak I (Waters Associated, Milford, USA) column of stainless steel (300 mm length × 6.5 mm internal diameter). Details of the used method were given by Bartolomé *et al.* (1995).

Data were statistically analysed using the Statgraphics Statistical Graphics System, Version 5.0. The software was provided on an 'as-is' basis. All data were subjected to an analysis of variance (ANOVA) and mean separation was by Duncan's multiple range test at $P \leqslant 0.05$. Significant differences were indicated by different letters in the same row/column. The method of least square was used to determine linear regression equations.

Table 1. Morphological characteristics of pineapple fruit before processing

Characteristic	Cultivar	
	Red Spanish	Smooth Cayenne
Fruit weight (g) (without crown)	927.0[b]	2060[a]
Crown weight (g)	60.0[b]	290.0[a]
Fruit length (cm)	11.6[b]	17.9[a]
Maximum fruit diameter (cm)	11.1[a]	13.3[a]
Shape	Round	Elongated
Skin colour	Reddish	Brownish
Leaf colour	Reddish green	Green
Flesh colour	Pale yellow	Intense yellow
Taste	Sweet-acid	Sweet

Mean value of at least 15 determinations.
Different superscript letters in the same row indicate significant differences, $P \leqslant 0.05$.

Table 2. Soluble solids (°Brix) of pineapple fruit slices during frozen storage

	Cultivar	
	Red Spanish	Smooth Cayenne
Fresh product	10.33[d]	12.48[cd]
Storage months at −18°C		
0	10.61[cd]	13.71[bc]
1	13.20[a]	13.30[c]
2	12.51[ab]	11.71[d]
4	12.35[ab]	15.20[ab]
6	10.88[cd]	12.25[cd]
8	11.46[bc]	15.05[ab]
12	10.36[d]	15.17[a]

Different superscript letters in the same column indicate significant differences, $P \leqslant 0.05$.

RESULTS AND DISCUSSION

The main morphological characteristics of the two pineapple fruit cultivars (Red Spanish and Smooth Cayenne) before processing are summarized in Table 1. Significant differences were found in fruit weight, crown weight and fruit length of both cultivars. Soluble solids contents of pineapple fruit slices in the fresh product, after freezing and during frozen storage are shown in Table 2. The soluble solids of fresh pineapple fruit slices did not change significantly during freezing in the two cultivars studied. A small increase was observed in this parameter during frozen storage. After 1 year of frozen storage, there was a significant difference ($P \leqslant 0.05$) in Smooth Cayenne, but the values in Red Spanish were similar to those of the fresh product. Slices of the cultivar Smooth Cayenne showed higher soluble solids values than the cultivar Red Spanish, which were correlated with the greater sugar content of this pineapple fruit.

Soluble sugars in fresh pineapple fruit detected by HPLC were sucrose, glucose and fructose. Results of their changes during the freezing process and frozen storage are shown in Table 3. The total sugar content was obtained by addition of sucrose, fructose and glucose amounts from each chromatogram. It is well established in the literature that the cultivar will affect the amount of total sugar, as well as the proportion of individual sugars in pineapple fruit (Hodgson & Hodgson, 1993). The data presented here support this view.

Values of sucrose in cv. Red Spanish (4.58%) were similar to those of cv. Smooth Cayenne (4.49%). Levels of glucose and fructose were higher in Smooth Cayenne (1.45 and 2.21%, respectively) than in Red Spanish (0.46 and 1.40%, respectively). The total soluble sugars and the fructose and glucose amount for the cultivar Smooth Cayenne fell within the range reported by Dull (1971). The results obtained in this cultivar are in agreement with Wills *et al.* (1986) (1.9% fructose, 1.4% glucose, 4.7% sucrose) and Luh *et al.* (1986) (1.9% fructose, 1.6% glucose and 4.8% sucrose). In pineapple fruit the sucrose amount was approximately two-thirds of total sugars (Luh *et al.*, 1986).

Table 3. Soluble sugars of pineapple fruit slices during frozen storage

Fresh sugars (% fresh weight)	Variety	Fresh	Storage months at −18°C 0	1	2	4	6	8	12
Sucrose	Smooth Cayenne	4.50^{bc}	4.91^{abc}	4.62^{bc}	5.74^{abc}	6.87^{ab}	6.21^{abc}	6.95^{ab}	7.98^{a}
	Red Spanish	4.59^{d}	4.77^{d}	5.59^{cd}	5.99^{bc}	7.44^{a}	6.66^{abc}	6.15^{bc}	6.72^{abc}
Glucose	Smooth Cayenne	1.45^{bc}	2.05^{abc}	1.50^{bc}	2.13^{abc}	2.45^{ab}	1.82^{abc}	2.01^{abc}	2.88^{a}
	Red Spanish	0.46^{cd}	0.44^{cd}	0.29^{d}	0.64^{bc}	1.01^{a}	0.71^{bc}	0.71^{bc}	0.73^{abc}
Fructose	Smooth Cayenne	2.21^{ab}	2.62^{ab}	2.06^{ab}	2.70^{ab}	2.94^{ab}	2.55^{ab}	2.50^{ab}	3.40^{a}
	Red Spanish	1.40^{bc}	1.37^{c}	0.66^{d}	1.60^{bc}	2.10^{a}	1.54^{bc}	1.76^{ab}	1.71^{bc}
Total sugar	Smooth Cayenne	8.15^{bc}	9.59^{abc}	8.19^{bc}	10.57^{abc}	12.25^{ab}	10.58^{abc}	11.46^{ab}	14.26^{a}
	Red Spanish	6.44^{d}	6.58^{d}	6.54^{d}	8.23^{bc}	10.56^{a}	8.90^{bc}	8.61^{bc}	9.17^{abc}

Different superscript letters in the same row indicate significant differences, $P \leqslant 0.05$.

In cv. Red Spanish, the freezing process slightly increased the sucrose (4.0%) value and slightly decreased the glucose (3.9%) and fructose (2.1%) values. In this cultivar the sugar content is similar to the fresh product. In cv. Smooth Cayenne, the freezing process increased the sucrose (9.2%), glucose (42%) and fructose (18.6%) values. The freezing process produced a slight increase in total sugar content in the two cultivars, in agreement with previously reported studies in mango cultivars (Marín *et al.*, 1992). This could be due to easier extraction after cell-wall rupture caused by ice crystal formation during the freezing process. No significant changes ($P \leqslant 0.05$) were found during frozen storage of the two pineapple fruit cultivars. After 1 year of frozen storage there was an increase in sucrose (62.5% in Smooth Cayenne and 40.9% in Red Spanish), glucose (40.5% in Smooth Cayenne and 65.9% in Red Spanish) and fructose (29.8% in Smooth Cayenne and 24.8% in Red Spanish). The increase in total sugars was 48.7% in cv. Smooth Cayenne and 13.5% in cv. Red Spanish.

A high correlation was observed in the two cultivars of pineapple fruit between the different sugars during frozen storage. In cv. Smooth Cayenne the correlation coefficients were $r = 0.95$ for total sugar/glucose, $r = 0.93$ for total sugar/fructose and $r = 0.98$ for fructose/glucose ratios. In cv. Red Spanish the correlations were $r = 0.91$ for total sugar/glucose, $r = 0.85$ for total sugar/fructose and $r = 0.96$ for fructose/glucose ratios. A positive correlation was observed between the total sugars determined by HPLC and the total soluble solids (TSS); $r = 0.69$ for cv. Smooth Cayenne and $r = 0.51$ for cv. Red Spanish (Walter, 1992), although the measurement of TSS was always higher. Since TSS measures not only the sugars but all dissolved substances, which have a different refractive index from that of water (acids, salts, etc.), this result was to be expected.

From the results for soluble solids, reducing sugars (glucose and fructose) and total sugars, we can conclude that no important changes in sugar content are associated with the freezing preservation of pineapple fruit slices.

ACKNOWLEDGEMENTS

A. P. Bartolomé thanks the Spanish Ministerio de Educación y Ciencia for her scholarship. This research was supported by the Comisión Interministerial de Ciencia y Tecnología (grants ALI 88-0180 and ALI 91-0621).

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