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Food Chemistry 53 (1995) 75–79
Elsevier Science Limited
Printed in Great Britain.
0308-8146/95/$9.50

Pineapple fruit: morphological characteristics, chemical composition and sensory analysis of Red Spanish and Smooth Cayenne cultivars

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(Received 15 June 1994; revised version received and accepted 12 October 1994)

Some physical (weight, size, shape, texture and colour), physico-chemical (pH, titratable acidity and soluble solids), chemical (soluble sugars and organic acids) and biochemical (total dietary fibre, peroxidase activity and soluble protein) characteristics and sensorial attributes (appearance, flavour, odour, colour, firmness and acceptability) of pineapple (*Ananas comosus* L.) fruit were studied, in order to assess nutritional properties and consumer acceptability of the local Red Spanish and imported Smooth Cayenne cultivars. Significant differences ($P \leq 0{\cdot}05$) were found between size, shape and colour of the cultivars, and also between other objective (lightness, green colour, total acidity, soluble solids, total dietary fibre, peroxidase activity, fructose and glucose) and subjective (colour) measurements. Values of texture, fibre content and soluble solids to acid ratio were lower in the Red Spanish cultivar, while peroxidase activity and soluble protein were higher. Taste panelists preferred the appearance, colour and firmness of the Red Spanish pineapple slices.

INTRODUCTION

Pineapple is grown extensively in Hawaii, Philippines, Caribbean area, Malaysia, Taiwan, Thailand, Australia, Mexico, Kenya and South Africa. Among the principal varieties are 'Smooth Cayenne' and 'Red Spanish'. The pineapple has long been one of the most popular of the non-citrus tropical and subtropical fruits, largely because of its attractive flavour and refreshing sugar–acid balance. The chemical and physical development of pineapple fruit (cv. Smooth Cayenne) has been extensively studied (Gortner, 1965; Gortner & Singleton, 1965; Singleton, 1965; Singleton & Gortner, 1965). 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) and Kermasha *et al.* (1987).

Pineapple undergoes changes during maturation and ripening. As the fruit ripens, the 'eyes' change from pointed to flat, with a slight hollowness at the centre; the fruit becomes enlarged, less firm and more aromatic. The shell colours of pineapple are generally used to determine the various stages of maturity. 'Red Spanish, develops a reddish-brown, yellow or light orange colour, while Smooth Cayenne produces a light yellow or golden yellow colour when ripe. Pineapples with slightly yellowed to one-half yellowed surface have better shelf-life than those with more surface colour, and fruits with no yellowing may not be mature enough for optimum quality (Pantastico, 1975).

Indices of physiological maturity and eating quality in Smooth Cayenne pineapples were given by Smith (1988*a*; 1988*b*), Tisseau (1984), and Reinhardt *et al.* (1987). Available data on the composition of pineapple varieties from America (Smooth Cayenne, Red Spanish, etc.) were reported by Huet (1958) and Hodgson and Hodgson (1993). Quality and morphological characteristics of cvs. Smooth Cayenne and Red Spanish were studied by Bonnasieux (1988). Some characteristics of the chemical composition and general quality of the Red Spanish pineapple variety were given by Iglesias (1981) and Díaz *et al.* (1983). We have found very little data on cv. Red Spanish from the Canary Islands (Galán *et al.*, 1988).

The pineapple fruit sold at the local markets in Spain is Smooth Cayenne cultivar of tropical origin (Ivory Coast mainly). During the past few years, pineapple fruit culture was introduced in one of the Canary Islands (Hierro, Spain), because it is very windy and presented problems for banana plant growth. Some different cultivars were tried, but nowadays only cv. Red Spanish is grown. The fruits are primarily for local consumption.

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The aim of this study was to determine and compare the morphological characteristics, chemical composition and sensory acceptability of two cultivars of pineapple fruits, Red Spanish from Canary Island (Spain) and Smooth Cayenne from Ivory Coast.

MATERIALS AND METHODS

Raw material

Pineapple fruits (*Ananas comosus* L.) Red Spanish and Smooth Cayenne cvs. from Canary Islands and Ivory Coast, respectively, were obtained from commercial sources. Fruits were stored at 8 ± 1°C and 80–90% relative humidity (Bartolomew & Paull, 1986; Cancel, 1974) until analyzed.

Fruits were selected with similar characteristics of ripening (skin colour, flat eyes and degrees Brix), hand-peeled, cored, sliced and cut into small pieces before analysis. At least three separate measurements were performed at each analysis.

Physical determinations

Texture

Texture evaluation was carried out according to the Kramer Shear test in an Instron 1140 texturometer. Fifty grams of sectioned slices (1·3 cm thick) were laid in the Kramer cell. A force of 200 kg was applied at a crosshead speed of 50 mm/min and a chart speed of 100 mm/min. The mean value for maximum force was calculated. The results were reported as resistance to shear in N/g fresh weight.

Colour

Colour was measured in a pineapple–water (4:1, w:v) purée with a Hunterlab D25 A-9 Tristimulus Colorimeter. A standard white tile having reflectance values of X = 82·51, Y = 84·53, Z = 101·23 was used as reference. A representative sample of the purée was put into a plastic dish (6 cm diameter and 1·5 cm high), and measured. Each value represents a mean of a duplicate determination of three different samples. Results were reported as an average of individual values as L (lightness), a (+a = red, –a = green) and b (+b = yellow, –b = blue).

Physico-chemical determinations

pH

Ten grams pineapple fruit was minced and blended with 40 ml deionized water in a Sorvall Omnimixer. The resulting mixture was cooled to 20°C. The pH was measured at this temperature with a Crison pH meter.

Titratable acidity

After determining the pH, the solution was titrated with 0·1N NaOH up to 8·1 pH. The results were expressed as percentage of citric acid (g citric acid/100 g fresh weight).

Soluble solids

Soluble solids were measured in the exudate from the Kramer Shear cell with an Atago digital refractometer dbx-30 at 20°C. Results were reported as degrees Brix.

Chemical determinations

Soluble sugars

The most important soluble carbohydrates in pineapple (sucrose, fructose and glucose) were analyzed by HPLC (Bartolomé, 1992) using a Hewlett Packard model 1040 instrument with a Refractive Index detector model HP 1047A, employing a Sugar Pak I (Waters Associates, Milford, USA) column of stainless steel (300 mm length × 6·5 mm internal diameter). The eluent was 0·1 mM calcium acetate working at 90°C and the flow rate was 0·8 ml/min. Chromatographic standards in watery solution were: sucrose, 16·91 mg/ml; fructose, 7·49 mg/ml; and glucose, 5·27 mg/ml. Soluble sugars in the samples were quantified comparing peak areas. Results were reported as g soluble sugar/100 g fresh weight.

Sample preparation: Ten grams minced pineapple was homogenized with 40 ml methanol in a Sorvall Omnimixer at 2°C. The homogenized was refluxed for 30 min at 50°C on a water bath. The mixture was filtered through a Whatman No. 1 filter paper on a Büchner funnel and the residue was washed with methanol. The filtrate was evaporated under vacuum at 50°C in a Büchi rotavapor and the residue redissolved in 50 ml distilled water. This solution was filtered through glass wool, cleaned up through a Sep-pak C18 cartridge (Waters Associates) and filtered through a 0·45 μm Millipore filter. The injection volume was 10 μl.

Organic acids

The analysis of non-volatile organic acids in pineapple was carried out by HPLC, with a Diode Array UV-vis detector working at 214 and 254 nm, as described by Cano *et al.* (1991). The column was an Ion-300 organic acids column (Interaction). The eluent was 8·5 mN sulphuric acid working at 42°C and the flow rate was 0·4 ml/min. Chromatographic standards were 18·56 μg/ml oxalic, 0·94 mg/ml citric, 0·61 mg/ml L-malic, 0·07 mg/ml quinic and 0·07 mg/ml succinic acid. Acids were quantified by comparing peak areas. Results were reported as g acid/100 g fresh weight.

Sample preparation: The extraction procedure for non-volatile organic acids and soluble sugars was the same. The injection volume was 20 μl.

Biochemical determinations

Total dietary fibre

Total dietary fibre was assayed in 10 g fresh pineapple fruit (Bartolomé & Rupérez, 1992) according to the enzymatic gravimetric AOAC method (1985) modified by Prosky (1986).

Peroxidase (POD) activity

POD (EC 1.11.1.7.) activity of the enzyme extract was

determined by measuring the increase in absorbance at 460 nm, using o-dianisidine as chromogenic indicator (Fúster & Préstamo, 1989) in a Perkin–Elmer Lambda 15 UV-vis double beam spectrophotometer, equipped with a recorder. Ten grams minced pineapple fruit was homogenized with 20 ml 0·05 M sodium potassium phosphate buffer pH 6·0, in a Sorvall Omnimixer at 2°C. The enzyme extract was filtered through glass wool and centrifuged at 6000 rpm and 4°C for 20 min. An aliquot, appropriately diluted, was used for the enzymatic assay. The reaction mixture contained: 2·8 ml 0·05 M sodium acetate buffer pH 5·5, 0·2 ml 0·5% hydrogen peroxide (w/v), 0·1 ml 0·25% o-dianisidine (w/v) and 0·05 ml enzymatic extract. Each value represents a mean of a duplicate determination of three different samples. POD activity was expressed as Δ absorbance/min/mg protein.

Soluble protein

Soluble protein was measured in the enzymatic extract using the Bio-Rad protein assay method (Bradford, 1976) with bovine serum albumin as standard.

Sensory analysis

A 10-trained-members panel was selected to evaluate the pineapple fruit cultivar quality. The sensory laboratory complied with the UNE norms (1976). A 1–5 structured scale was used for appearance, flavour, odour, colour, firmness and overall acceptability of small pieces of sliced pineapple fruit. For *appearance*: 1, good; 2, fairly good; 3, acceptable; 4, slightly bad; 5, bad; *flavour*: 1, sweet; 2, fairly sweet; 3, sweet-sour; 4, fairly sour; 5, sour; *odour*: 1, characteristic; 2, slightly characteristic; 3, off-odours; *colour*: 1, bright yellow; 2, pale yellow; 3, slightly brownish yellow; 4 brownish yellow; 5, brown; *firmness*: 1, very firm; 2, firm; 3, fairly firm; 4, slightly firm; 5, soft; *overall acceptability*: 1, likes very much; 2, likes slightly; 3, accepts; 4, dislikes slightly; 5, dislikes.

Statistical analysis

Data were statistically analyzed by an analysis of variance (ANOVA) and mean separation was by Duncan's multiple range test at $P \leq 0{\cdot}05$. Significant differences were indicated by different letters in the same row.

RESULTS AND DISCUSSION

The main morphological characteristics of the two pineapple fruit cultivars are summarized in Table 1. Red Spanish pineapple fruit is smaller in size and its length to diameter ratio lower than Smooth Cayenne. The average fruit weight and the length to width ratio in the cv. Smooth Cayenne, agreed with the values reported by Singleton (1965) for ripe pineapple fruit. Regarding taste, cv. Smooth Cayenne was sweeter than cv. Red Spanish. Large pineapple fruit is, for the same stage of ripeness, less acid and sweeter than small. Among the parameters more suitable to grade pineapples into classes of physiological maturity were (in the case of the intact fruit), skin colour (shell colour) and (in the case of the flesh), translucency and flesh colour (Smith, 1988*a*). Significant differences ($P \leq 0{\cdot}05$) were found in fruit weight, crown weight and fruit length between cultivars.

Table 1. Morphological characteristics of pineapple fruit

Characteristics	Cultivar	
	Red Spanish	Smooth Cayenne
Fruit weight (g) (without crown)	927·0*b*	2060·0*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	Yellow
Taste	Sour	Sweet

Mean value of at least 15 determinations.
Different letters in the same row indicate significant differences, $P \leq 0{\cdot}05$.

Physical and physico-chemical determinations of pineapple fruit flesh are shown in Table 2. Texture values were higher in the cv. Smooth Cayenne, which was in agreement with its higher total dietary fibre (DF) content, although no significant statistical difference was detected. Differences in colour were observed in both cultivars, especially in '*-a*' parameter (green colour intensity), 2·37 times greener in the cv. Smooth Cayenne. Objective colour measurement indicated that the Red Spanish sample was less yellow in colour (lower '*b*' value) and brighter (higher '*L*' value). Significant statistical differences ($P \leq 0{\cdot}05$) were found for '*L*' and '*-a*' parameters. These results agreed with the

Table 2. Physical and physico-chemical determinations of pineapple fruit flesh

Assay	Cultivar	
	Red Spanish	Smooth Cayenne
Texture (N/g f.w.)	24·03*a*	32·69*a*
Colour		
L	73·22*a*	69·92*b*
a	–2·57*a*	–6·09*b*
b	24·22*a*	27·56*a*
pH	3·49*a*	3·54*a*
Titratable acidity (g citric acid/100 g f.w.)	1·17*a*	0·93*b*
Soluble solids (°Brix)	10·33*b*	12·48*a*

f.w. = fresh weight.
Different letters in the same row indicate significant differences, $P \leq 0{\cdot}05$.

obtained values in the sensory analysis, where significant differences in colour were observed, 1·89 in cv. Red Spanish (pale yellow a little bright) and 2·56 in cv. Smooth Cayenne (slightly brownish yellow).

No significant differences were found in the pH values, but there were significant differences ($P \leq 0{\cdot}05$) for titratable acidity and soluble solids (Table 2). The acidity, expressed as grams of citric acid per 100 g fresh weight, was higher in the Red Spanish cv. while the soluble solids was 2·2°B higher in the other cultivar. The soluble solids to acid ratios were 8·83 (cv. Red Spanish) and 13·4 (cv. Smooth Cayenne). In both cultivars the pH value was close to that reported by Singleton and Gortner (1965). The acidity and soluble solids values found for the cv. Smooth Cayenne fell within the range reported by Dull (1971) and Cano *et al.* (1994). The selected parameters to predict eating quality in pineapples were: % total soluble solids (TSS), titratable acidity, TSS/acid (also known as the Brix/acid ratio), pH, colour and translucency (Smith, 1988*b*). Flesh TSS was the only parameter found suitable as a year-round index of pineapple eating quality.

Significant differences ($P \leq 0{\cdot}05$) were also found in the biochemical analysis of both pineapple fruit cultivars (Table 3). The total dietary fibre (DF) content was 0·5 units higher in the cv. Smooth Cayenne, while POD activity and soluble protein values were significantly higher in the cv. Red Spanish. DF was higher in both cultivars than the values reported by Dull (1971), although in this case the method used was not mentioned. The obtained values of DF were similar to those of Lund and Smoot (1982, DF = 0·93) and Vidal-Valverde *et al.* (1982, DF = 1·46). POD activity and protein content during pineapple fruit development (cv. Smooth Cayenne) have been determined by Gortner and Singleton (1965), but the results were not comparable. Chemical determinations are also shown in Table 3. Total soluble sugars were higher in cv. Smooth Cayenne (8·16%), than in cv. Red Spanish (6·45%). No significant difference was found for sucrose. Different proportions of sucrose, fructose and glucose were detected in the cultivars (10:3:1 and 3:1·5:1, approximately for cv. Red Spanish and Smooth Cayenne, respectively). The total soluble sugars and the fructose and glucose for the cv. Smooth Cayenne fell within the range reported by Dull (1971), but sucrose content was lower and the sugars ratio was different. The results for soluble sugars in Smooth Cayenne were similar to those of Wills *et al.* (1986): 1·9% fructose, 1·4% glucose and 4·7% sucrose. Organic acids of pineapple fruit are shown in Table 3. The main organic acids of ripe pineapple fruit are citric and malic acid (Singleton & Gortner, 1965; Dull, 1971). Citric acid content was higher in cv. Red Spanish (1·27%) than in Smooth Cayenne (0·80%), but malic acid was slightly lower. The amounts of the main organic acids determined in both cultivars fell within the range reported by Dull (1971) and Cano *et al.* (1994), although the citric to malic acid ratio was different. Oxalic, quinic and succinic acid values were: 3·8, 26·0 and 19·9 mg/100 g fresh weight, respectively, in the cv. Smooth Cayenne, and trace amounts in the other cultivar.

Table 3. Chemical and biochemical determinations of pineapple fruit flesh

Assay	Cultivar	
	Red Spanish	Smooth Cayenne
Sucrose (% f.w.)	4·59*a*	4·50*a*
Fructose (% f.w.)	1·40*b*	2·21*a*
Glucose (% f.w.)	0·46*b*	1·45*a*
Citric acid (% f.w.)	1·27*a*	0·80*a*
Malic acid (% f.w.)	0·22*a*	0·38*a*
Fibre (% f.w.)	1·09*b*	1·63*a*
Peroxidase (Δ Abs/min/mg protein)	695*a*	442*b*
Soluble protein (mg/100 g f.w.)	25·0*a*	16·3*a*

f.w. = fresh weight.
Different letters in the same row indicate significant differences, $P \leq 0{\cdot}05$.

Table 4. Sensory analysis of pineapple fruit

Assay	Cultivar	
	Red Spanish	Smooth Cayenne
Appearance	2·33 ± 1·12*a*	3·11 ± 1·17*a*
Flavour	2·44 ± 0·88*a*	2·44 ± 0·73*a*
Odour	1·56 ± 0·53*a*	1·33 ± 0·50*a*
Colour	1·89 ± 0·33*b*	2·56 ± 0·73*a*
Firmness	2·00 ± 0·71*a*	2·33 ± 0·71*a*
Acceptability	1·78 ± 1·09*a*	1·89 ± 0·61*a*

Different letters in the same row indicate significant differences, $P \leq 0{\cdot}05$.

The results from the taste panel are shown in Table 4. Panellists preferred the appearance, colour and firmness of the Red Spanish pineapple fruit samples. Flavour and odour values were similar in both, and the overall acceptability was slightly higher for the cv. Red Spanish. Panellists were not able to distinguish the sample firmness and both were classified as 'firm'. Regarding colour, panellists considered that the cv. Red Spanish was pale yellow, while the cv. Smooth Cayenne was slightly brownish-yellow, results in agreement with Tables 1 and 2. As to the statistical analysis, the only significant difference detected by the taste panel was that of colour. The differences in titratable acidity and soluble solids were not detected by panellists.

The results from Tables 1–3 show lower quality parameters for Red Spanish; Smooth Cayenne has the more favourable characteristics.

ACKNOWLEDGEMENT

This work was supported by the Consejo Superior de Investigaciones Científicas. Plan Nacional de Tecnología de Alimentos (Spain). Project ALI 91-0621.

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