PHYSICAL - CHEMICAL ANALYSIS OF SELECTED QUENEPA (*Melicoccus bijugatus* Jacq) VARIETIES

By

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ABSTRACT

Tropical fruits are desired by international markets, especially by those markets in which Latin people predominate. In Puerto Rico, there are diverse varieties of quenepa (*Melicoccus bijugatus* Jacq.), which present different characteristics as to size, shape, flavor, quantity of pulp, time of harvest, and others. The original distribution of this fruit extends from northern South America, to Central America and the Caribbean. The objective of this study was to determine pulp adherence to the seed and the differences in physical-chemical properties of selected varieties of quenepa grown in Puerto Rico.

Ten varieties ´Perfa´, ´Jose Pabón´, ´Sotomayor´, ´ Doña Fela´, ´Sasa´, ´Martínez´, ´Las Cuevas´, ´César Ramos´, ´Alina´ and ´Carmen´, were evaluated for yield of pulp, pulp adherence (pressure), total soluble solids, color, pH, titratable acidity and organic acids. The results showed that the percent of pulp varied from 38 – 53%. The pressure of extraction was an indicator of pulp adherence to the seed. The lowest value was 3.4 PSI and the highest value was 12.0 PSI. In addition, the quantity of soluble solids varied between 18 and 22 °Brix. The predominant acids in the fruit are citric acid, malic acid, succinic acid, acetic acid using HPLC method. The column used was Supecogel C-610 H.

RESUMEN

Las frutas tropicales son deseadas por mercados internacionales, sobre todo por aquellos mercados en los cuales predomina la población latina. En Puerto Rico, se han encontrado gran variabilidad en quenepa (*Melicoccus bijugatus* Jacq.), cada una de las cuales con características distintivas, tales como el tamaño, el sabor, la cantidad de pulpa, tiempo de cosecha, y otras. El objetivo principal de este estudio fue determinar la adherencia de la pulpa a la semilla y las diferencias en las características físico–químicas de variedades selectas de quenepa de Puerto Rico.

Diez variedades ´Perfa´, ´Jose Pabón´, ´Sotomayor´, ´ Doña Fela´, ´Sasa´, ´Martínez´, ´Las Cuevas´, ´César Ramos´, ´Alina´ and ´Carmen´, fueron evaluadas en cuanto a rendimiento de la pulpa, adherencia de la pulpa (presión) contenido de sólidos solubles totales, pH, la acidez, color y ácidos orgánicos. Los resultados muestran que el porcentaje de pulpa varía entre 38 – 53%. La presión fue empleada como un indicador de cuan adherente es la pulpa encontrando que la menor presión fue de 3.4 PSI y la mayor presión requerida para la extracción fue de 12.0 PSI. La cantidad de sólidos solubles totales varió entre 18° y 22° Brix. Los ácidos orgánicos predominantes en la frutas fueron el acido cítrico, málico, succínico, acético, analizados por el método de HPLC, usando la columna para determinación de ácidos orgánicos Supecogel C-610 H.

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LIST OF ABBREVIATIONS

Pf: ´Perfa´

JP: ´José Pabón´

Fe: ´ Doña Fela´

Sm: ´Sotomayor´

Sa: ´Sasa´

Ma: ´Martinez´

Cu: ´Las Cuevas´

CR: César Ramos´

Al: ´Alina´

C: ´Carmen´

AOAC: Association of Official Analytical Chemists

HPLC: High Performance Liquid Chromatography

INTRODUCTION

The quenepa, *Melicoccus bijugatus* Jacq. (genip in English and also known as Spanish lime in Florida) is considered by horticulturists as one of the minor tropical fruits of the family Sapindaceae. The fruit is botanically classified as a drupe, commonly of spherical or ovoid shape, from 2 to 4 cm in diameter. The exocarp or rind is smooth or granular, thin and coriaceous and fragile, with a green or greenish yellow color in the exterior and white interior. The mesocarp (edible portion or pulp) is brilliant, translucent, and has a gelatinous, juicy texture with a sweet acidulated flavor. The pulp, which generally adheres strongly to the seed, varies from salmon-like to yellow to orange color. The endocarp or seed container is hard. Generally the fruit contains only one seed, though on occasions two hemispheric seeds can be found. The seminal covers are whitish yellow, 1.5 to 3 cm in diameter surrounding the seed (Cruz and Torres, 2002).

This fruit is harvested during late summer, mainly in the months from July to September. The pulp develops an agreeable bittersweet flavor when mature, but when unripe a bitter flavor prevails (Morton, 1987). Some studies described a flavor similar to that of seedless green grapes (Francis, 1992).

Acevedo–Rodríguez (2003) reported that *Melicoccus bijugatus* is usually available during the fruit season (July and September) along roadsides and on markets in Colombia, French Guiana, Guyana, New York City, Puerto Rico, and Venezuela. In Puerto Rico it is also used to prepare an alcoholic drink called “bilí”. This alcoholic drink is made on the island of Vieques by aging rum with the fruits.

According to the data provided by the Administration of Services and Agricultural Development of the Department of Agriculture of Puerto Rico, the peak of quenepa season is during August and the first week of September. There are only a few commercial farms of quenepa in Puerto Rico and most of the harvest comes from wild trees. Most of the crop is consumed locally but part is exported to the United States. The commercial production was estimated in approximately 1,426 bunches during 2001 fiscal year. The gross income from quenepa represents nearly 9 % of the total gross income generated by fruits for the year 2000 (Departamento de Agricultura, 2001). This contribution can increase if new marketing alternatives are established based on the improvement of the quality and uses of the fruit.

Quenepa is consumed as fresh fruit by removing the exocarp and sucking the juicy pulp until the seed is bare. Consumption, especially by young children, can be dangerous because most varieties found in the market have small seeds that could cause choking (Francis, 1992).

Objectives

The purpose of this study was to establish a basic characterization of selected varieties of quenepa (*Melicoccus bijugatus* Jacq.*)* on the island of Puerto Rico. This is needed in order to improve commercial production of the fruit, which has gained economic importance both in local markets and for export.

The main objectives of this study are:

1. Determine the degree of pulp adherence to the seed in quenepa fruits (*Melicoccus bijugatus* Jacq.) and its relation to the postharvest storage of the fruit.
2. Determine the applicability and efficiency of different mechanical pulp extraction methods.
3. Determine physical – chemical characteristics of different quenepa varieties (color, predominant acid of the fruit, pH, and acidity, total soluble solids, size and harvest index).

Literature Review

The tropical tree, *Melicoccus bijugatus* Jacq., is indigenous to the Western Hemisphere. The area of distribution of this fruit extends from northern, South America, to Central America and the Caribbean (Figure 1) (Francis, 1992).

Figure1. Natural distribution of quenepa (*Melicoccus bijugatus).*

The tree grows well up to 1000 m above sea level. The edible fruit produced by this plant is known by many common names: quenepa, mamoncillo, genip, honeyberry, spanish lime, and others (Jackson, 1967). It is sometimes described as an acidic fruit of bland or disagreeable flavor, with pulp difficult to remove from the seed. The observation of flesh adherence to the seed while eating the fruits is a common method for determine adherence in rambutan (Vanderlinden et al., 2004).

Unlike its oriental relatives the litchi, longan and rambutan, the quenepa is strictly an American plant. The outer covering of these fruits is thick and green on the surface; it encloses a large round seed surrounded by soft, pinkish orange, translucent, juicy pulp. The flavor is pleasant and sweet but in many varieties can be acidic if the fruit is not fully ripe (Popenoe, 1974).

Jackson (1967) conducted extensive studies on cultivar selection in Puerto Rico. Samples of fruit were collected from trees and taken to the laboratory for physical and chemical evaluation. The varieties were identified as (Sample A, B, C, D, E, F, G, H and J) where Puerto Rico #1 (Sample A), Puerto Rico #2 (Sample D), Puerto Rico #3 (Sample G) and Puerto Rico #4 (Sample J) were selected with the most promising characteristics based on the percentage of edible matter and sugars. Percentage of edible matter ranged from 46.6% to 48.6% and percentage of sugar was 26%, 24.1%, 24.1% and 22.7%, respectively.

Campbell (1976) in Morton 1987 studied three varieties named No. 2 (´Queen´), No 3 and No. 4 (´Montgomery´) according to individual characteristics, including pulp percent. He found that the percentage of pulp was 55.6%, 48.2% and 51.5%, respectively.

In many countries studies of *Melicoccus bijugatus* have been limited to plants selected by high yield, percent of edible pulp and fruit size (Avilan et al., 1980). Meyer and Paltrinieri (1981) explain methods of peeling in fruits. For example chemical peeling in peaches; can immersed in 10% NaOH solution, at 60ºC by 1 minute, this process permit a total remove of peel. Nevertheless, the result of excessive exposition produces a total removal of the pulp. After of immersion in NaOH, the fruit is immersed in water and then immersed in a solution of 2 % citric acid.

Some superior cultivars have been selected in the Antilles. These cultivars present differences in size and acidity of the fruit. *Melicoccus bijugatus*, is propagated principally by seed, but superior clones are usually propagated by grafting (León, 1987).

The nutritional value of the Colombian quenepa (*Melicos bijugatus*) (Francis, 1992) is shown in Table 1.

Table 1. Nutritional value of *Melicoccus bijugatus* (100g of pulp).

Calories	73 Cal
Humidity	77 g
Protein	1.0 g
Fat	0.2 g
Carbohydrates	19.0 g
Fiber	2.0 g
Ash	0.4 g
Calcium	3.4 mg
Phosphorus	50 mg
Carotene	0.02 mg
Thiamine	0.02 mg
Riboflavin	0.01 - 0.20 mg
Niacin	0.8 mg
Ascorbic Acid	10 mg

Respiration, transpiration, chemical composition, external appearance, anatomical structure, taste quality and postharvest behavior of fruit partly reflect environmental conditions, such as temperature, light, soil texture, wind, rainfall, mineral nutrition, chemical sprays, irrigation and drainage in areas where trees are grown. The nutritional value of the fruits may vary according these factors, for example, the ascorbic acid content may increase due to the use of fertilizers high in K, Mg and Zn and decrease by fertilizers high in N and P (Pantastico, 1975)

Despite these harvest characteristics, poor quality may also result from metabolic changes due to mechanical damage, pests and disease as well as physiological disorders induced by some factors like high or low temperatures (Mitra, 2001).

Girard and Kopp (1998) studied the physicochemical characteristics of selected sweet cherry cultivars. Organic acids were characterized and quantified by high performance liquid chromatography. Fruit weight, total soluble solids, titratable acidity, fruit size and color (L, a, b) were also determined at harvest.

Fruit ripening can be considered as an aspect of development that is triggered by the achieving of the necessary hormonal balance together with the programming of cells to respond to such a change. These changes in chemical composition are principally total soluble solids, titratable acidity, protein and sugars. Abbas and Fandi (2002) reported that the total soluble solids and titratable acidity are low during the early stages of fruit development. Sugars are also low initially and increase slowly.

According to Barbosa-Cánovas et al., (2003), the stages of maturity at which a fruit or vegetable should be harvested is crucial to its subsequent storage and marketable life and quality. Postharvest physiologists distinguish three stages in the life span of fruits and vegetables: maturation, ripening, and senescence. Maturation is indicative of the fruit being ready for harvest. At this point, the edible part of the fruit or vegetable is fully developed in size, although it may not be ready for immediate consumption. This parameter may be determined as the Brix/acidity ratio, which increases as the fruit ripens. Ripening follows or overlaps maturation, rendering the produce edible, as indicated by taste. Senescence is the last stage, characterized by natural degradation of the fruit or vegetable, as in loss of texture, flavor, etc. (senescence ends at the death of the tissue of the fruit). Some typical maturity indexes are described based on skin color, shape, size, firmness, sugars, acidity and others. Cruz (2002) mentioned that the quenepa is a non-climateric fruit but no studies were found to support this fact.

The lychee industry has a minimum maturity standard, for example, fruits below a minimum brix: acid ratio of 35:1 is required by markets. It is designed for use by market inspectors and is difficult to measure on the farm. The brix:acid ratio measure the balance between sugars and acids in the fruit (Greer, 1990).

Many countries, especially those exporting fruit and vegetables, establish quality determinants that include size, color and maturity, however, each country has its own criteria depending on local circumstances and markets. The consumer also places importance on appearance (size, color and shape), condition and absence of defects, texture, flavor and nutritional value (Wills et al., 1982). Wills describes size as important criteria of quality which can be easily measured either by circumference, diameter, length, width, weight or volume. Shape is a criterion that often distinguishes particular cultivars of fruit, usually demanded by the consumer who will often prefer the characteristic shape.

The color and appearance of food is critical to determine whether or not a food will be purchased and consumed. Also are considered very important in the quality of fruit. Color may vary according to variety or maturity (Inglett, 1979). The preferred quenepa is a salmon-yellow, yellow bleshed quenepas are undesirable. Color changes can result from chilling, mechanical or microbiological injuries.

Color can be objectively measured using a variety of reflectance or light transmittance spectrophotometers. The Hunter, Color Difference Meter is an example which is widely used in research work (Wills et al., 1982).

One important characteristic for the consumer acceptance of the quenepa fruit is the adherence of the pulp to the seed. The observation of flesh adherence to the seed while eating the fruits is a common method for determine adherence in rambutan (Vanderlinden et al., 2004).

Organic acids are important constituents of plant foods, influencing flavor, stability and keeping quality. Organic acids are generated in the Krebs cycle during aerobic oxidation of carbohydrates, fats and proteins in most biological systems (Picha, 1985). These acids are distributed widely in the fruits and vegetables, and predominantly in the form of citric and malic acids. These acids are responsible for development of acceptable flavors and their stability before deterioration. Also considered are phenolic compounds which can be responsible for multiple biological effects contributing properties such as antioxidants, and antibacterial agents (Shui and Loeng, 2002).

The nature and concentration of organic acids in fruits are of interest due to their great influence on the organoleptic properties. Since each fruit has a unique pattern of organic acids, chromatographic analysis of organic acid can be applied to verify juice authenticity. In addition, the acidic properties of organic acids are used in addition to sugar contents as the main index of maturity and a major analytical measure of flavor quality (Hyoung, 1993)

High performance liquid chromatography (HPLC) is a useful technique for quantifying organic acids in many natural products. Shaw and Wilson (1983) studied amounts of individual acids present in fruits and how this content changed as the fruits ripens.

MATERIALS AND METHODS

Fruit sampling

Ten varieties of quenepa (*Melicoccus bijugatus* Jacq.) cultivated at Juana Díaz Experiment Station of the University of Puerto Rico and in some private farms in the south west region were used for this study. Trees with relevant fruit characteristics (size, yield, harvesting season) had been previously identified in different localities of the island (Figure 2) (Cabo Rojo, Sabana Grande, Peñuelas, Ponce, Boquerón and Juana Díaz). The varieties used in this study were ´José Pabón´, ´Perfa´, ´Doña Fela´, ´Sotomayor´, ´Sasa´, ´Martínez´, ´Las Cuevas´, ´César Ramos´, ´Alina´, and ´Carmen´. They were harvested during the months of July and August 2005 and 2006. Harvesting time begins approximately ninety days after flowering when bunches of fruit are hand picked from the trees, (based on their degree of maturity and according to fruit size and color). In the present study fruits were collected from the field, packed in boxes and brought to the laboratory for analysis. Fruits were initially kept at ambient temperature and then transferred to air conditioned facilities at the laboratory until sampling.

Figure 2. Study area (Cabo Rojo, Sabana Grande, Juana Díaz, Peñuelas, Boquerón, Ponce). www.ccsu.edu/images/ pr-municipalities.gif

Texture analysis

The texture meter used was Texture – analyzer TAXT2 Stable Microsystem (Texture Technologies Corp.). Results are expressed as the force necessary to penetrate the mesocarp of the fruit. Prior to analysis the rind was removed and measurements were taken using a stainless steel needle probe code P/2N. With a force of 35 grams, and a test speed of 10 mm/s, the penetration distance was between 1 and 3 mm.

Weight of fruit, seed and pulp

Thirty fruits per variety were weighed with a Mettler PJ360 Delta Range scale. After using a chemical peeling with NaOH 10% (Bernal de Ramirez, 1993) was used to determine the percentage of pulp and seed. The fruits were individually submerged in the 10% NaOH solution for 7 minutes at 50 C. The pulp was extracted. Seeds were removed from the solution, dried with paper towel and weighed. Finally the weight of the seed without the pulp was used to determine the maximum pulp yield, and to calculate the percentage of seed, pulp and peel (Equation 1).

Figure 3. NaOH solution.

Figure 4. Quenepa seed.

Extraction and adherence of the pulp by mechanical methods

Taking into consideration the form and texture of the fruit and adherence of the pulp to the seed it was estimated that the ideal method for removing the pulp should be based on friction or suction. In this form the detachment of the juicy flesh should be easier. Adherence of the pulp is a factor determining quality for consumer acceptability. Three methods were used to determine the adherence of pulp to the seed for this fruit.

Method 1 (food processor)

A Prinetty Deluxe NT – 0016 food processor was used for this method. In preliminary assays, it was determined that it was possible to remove the pulp in approximately 45 seconds. A sample of 100 g of peeled fruit was placed in the food processor. The time needed to remove most of the pulp was determined from the time the motor started. The instrument reached a velocity of approximately 500 rpm (rounds per minute). The weight of pulp and seed were also recorded. Then the percentage of pulp removed was calculated with the following formula:

$$\% \text{ pulp} = \frac{Wp}{Wtf} \times 100 \qquad \text{(Eq. 1)}$$

Where, Wp = weight of pulp, Wtf = weight of total fruits.

Method 2 (mixer)

In this method a conventional mixer (Premium Hand Mixer EM82821) with five speeds was used. The first or lowest speed was used to avoid damaging the pulp and seed. A 100 g sample was added to the bowl with a mesh, the mixer was started, and the time needed to remove most of pulp was recorded. The instrument reached a velocity of 400 rpm. The weight of the pulp and seed were also obtained. The percentage of pulp extracted was determined using Equation 1.

Method 3 (vacuum pump)

A vacuum pump (GE motors, model 1HAB-25 M 100 x) was used to establish the adherence of the pulp to the seed. One hundred grams samples of peeled fruit were sucked by the vacuum pump. The time and pressure needed to remove all pulp was measured.

Effect of storage at 4°C on pulp adherence

The vacuum pump method (GE motors, model 1HAB-25 M 100 x) was used to establish the effect of storage time on the adherence of the pulp to the seed. Based on previous experiments two varieties of quenepa were chosen for this purpose ´Sasa´ (Sa) a variety with least pulp adherence, and ´Martínez´ (Ma) a variety with highest adherence. The pressure and the time required removing the pulp of 30 fruit samples of each variety after 1, 4, 8, 12, 16 days of storage at 4ºC was measured. The values reported in inches of mercury (inHg) were converted to PSI units as follows

$$P_{PSI} = P_{inHg} \times 0.4912 \qquad \text{(Eq. 2)}$$

Where, P_{inHg} = Pressure reported by equipment, 0.4912 = conversion factor.

Color

The color of the pulp extracted was determined using a colorimeter, (Hunter XE Miniscan) scale CIELAB, Iluminant D65 and Observer 10°. The pulp was placed in a Petri dish and the color (CIE L, a, b) was determined. The average of three readings per quenepa sample was recorded.

Organic acids analysis

The AOAC method 942.15 was used to determine organic acids in the quenepa by high performance liquid chromatography (HPLC). The procedure used to extract and separate organic acids was modified from a method described by Lee (1993) mainly the modified conditions were based on column, mobile phase, temperature and, wavelength.

Puree sample preparation

The pulp of the fruits previously extracted was packed in a centrifuge tube and kept frozen until analysis.

Chemical and supplies

The organic acids standards were purchased from (Sigma –Aldrich. St Louis, MO). The SCX (benzensulfonylpropyl) extraction cartridge (100 mg) was obtained from Varian (Harbor City, CA). Disposable filters (0.45µm) were purchased from Fisher Scientific Co.

Reagents and preparation of the standard

A stock solution of 10,000 ppm was prepared including citric acid, L-ascorbic acid, DL-malic acid, succinic acid, maleic acid, fumaric acid, acetic acid, oxalic acid and L(+)tartaric acid, (Sigma - Aldrich). Working standard solutions of 1000 and 100 ppm were prepared. Standards were prepared in concentration of 100 ppm with mobile phase, and were filtered, before being injected into the chromatrograph HPLC system (Hyoung, 1993). They were diluted for a standard curve in concentrations ranging between 10 to 100 ppm depending on the organic acid to be measured. The concentration of each acid was calculated with the followings equations:

Organic acid	Equation	Equation number
Oxalic acid	$y = 190495x - 4408.3$	(Eq. 3)
Citric acid	$y = 19315x - 131255$	(Eq. 4)
Malic acid	$y = 13051x - 6114.9$	(Eq. 5)
Succinic acid	$y = 8938.3x - 624.83$	(Eq. 6)
Acetic acid	$y = 9516.9x - 17848$	(Eq. 7)

Mobile phase preparation

According to the specifications of the column manufacturer, the mobile phase must be H_3P0_4 0.1% with pH 2.2 (Supelco, Inc.). The mobile phase was filtered and degassed before injected to the equipment.

Equipment

A Hewlett Packard Series 1100 High Performance Liquid Chromatograph (HPLC) with a 30cm x 7.8 mm analytical column (Supecogel C-610 H Supelco, Inc.) and a Guard column (Supelguard C 610H, Supelco, Inc.) was used.

Organic acids extraction and separation

Organic acids were extracted from the frozen pulp. Four grams of the pulp were mixed with 8 mL of water and 1 mL of 2.5% meta-phosphoric acid. The sample was homogenized and centrifuged at 5000 rpm for 15 minutes. The cartridge SCX (Varian Inc.) was washed with 1mL of HPLC grade methanol (Fisher Scientific) and 10 mL of HPLC water. An aliquot of 1 mL of the centrifuged sample was placed in the cartridge, washed with 2 mL of HPLC water and collected inside a centrifuge tube. The volume was adjusted to 10 mL with the mobile phase (Hyoung, 1993). Other aliquots were taken for dilutions.

These solutions were filtered through a 0.45 μm of nylon membrane of (Supelco, Inc.) and were then injected directly into the HPLC.

Analytical conditions

Analysis of organic acid was carried out by injecting 25μL aliquots of sample and standard solutions. The organic acids were eluted isocratically with H_3P0_4 0.1% with pH 2.2. The eluate was monitored at 210 nm and 25°C at a flow rate of 0.5 mL/min.

pH determination

The Analysis of Association of Official Analytical Chemists (AOAC) method 10,041/84 was used for pH determination. The pH meter was standardized with buffer solutions of pH 4 and 7 at a constant temperature (20 º C) (Bernal de Ramírez, 1993). A sample of 50 – 75 grams of pulp was homogenized using a food processor. The pH was measured directly from the sample with the pH meter (AOAC, 1990).

Size

The length and diameter of thirty fruits was measured by caliper Mitutoyo (Barbosa-Cánovas et al., 2003). The spherical relation (SR = L/D) and volume ($4/3\pi r^3$) was determined from this measurement.

Figure 5. Caliper.

Total soluble solids

Total soluble solids were determined with an Abbe Refractometer as described in method AOAC 932.12/90 (AOAC, 1990). Twenty grams (20g) samples of pulp were extracted; a drop was then taken from the sample and placed in the refractometer. Values obtained were converted to degrees brix with a conversion table.

Titratable acidity

The AOAC 942.15/90 method was used to determine the titratable acidity of the samples. The extracted pulp (50g) was diluted with deionized water, homogenized in a food processor, and filtered with a Whatman # 4 filter. An aliquot (20 mL) was taken and was weighted. This aliquot was titrated with standardized 0.1N sodium hydroxide (NaOH).

The percent acid obtained was as follows:

$$\text{Eq NaOH} = \text{Vd x } N_{NaOH} \qquad \text{eq NaOH = eq Citric Acid}$$

$$\text{Citric acid g} = \text{eq citric acid x } \frac{64.04\text{ g}}{1\text{ eq-g Citric Acid}} \text{ x df}$$

$$\text{\% Citric acid} = \frac{\text{Citric acid g}}{\text{W aliquot}} \text{ x 100} \qquad \text{(Eq. 8)}$$

Harvest index

The harvest index was determined by correlating the titratable acidity with percent of soluble solids (Crisosto et al., 2002) for each variety (SS/TA) where, SS: Soluble Solids and TA: Titratable Acidity.

Statistical analysis

Differences between varieties and extraction method

Physical and chemical data was submitted to an analysis of variance (ANOVA) using InfoStat V.3.0. The source of variation was the variety of quenepa (*Melicoccus bijugatus* Jacq.). T-Tukey ($p<0.05$) was applied as with a level of significance of 5%.

RESULTS AND DISCUSSION

Fruit samples

Fruit samples were obtained from trees grown in various municipalities of Puerto Rico. The variety ´Perfa´ (Fig. 6) is a big fruit with a thick peel. ´José Pabón´ (Fig. 7) is juicy, and has easy to remove pulp; these varieties were collected from Jardines Eneida in Cabo Rojo. ´Doña Fela´ (Fig. 8) was collected from a tree in Sabana Grande; this variety has a small and the peel is easy to break. ´Martínez´ (Fig. 9) has a large number of fruits per bunch and fruits are small in size with the pulp very adherent to the seed. ´Sasa´ (Fig. 10) has a big fruit and the pulp is very soft and easy to remove. ´Sotomayor´ (Fig. 11) has a darker peel than other varieties, and was harvested from the Agricultural Experiment Station of the University of Puerto Rico in Juana Díaz. ´Las Cuevas´ (Fig. 12) has small fruit, with spherical shape; the rind is soft and the pulp is strongly adhered to the seed. ´César Ramos´ (Fig. 13) fruit presents a yellow-green rind, is small, has a pulp strongly adherent to the seed and is very acid. It was obtained in Peñuelas. ´Alina´ (Fig. 14) has a big fruit, and usually has two seeds per fruit which is known in Puerto Rico as “guareta”, and was collected from Ponce. ´Carmen´ (Fig. 15), similar to ´José Pabón´ in color and form, and is similar to ´Sasa´ because the pulp is easy to remove, was from Boquerón.

Figure 6. ´Perfa´.

Figure 7. ´José Pabón´.


Figure 8. ´Doña Fela´.


Figure 9. ´Martínez´.


Figure 10. ´Sasa´.


Figure 11. ´Sotomayor´.


Figure 12. ´Las Cuevas´.


Figure 13. ´César Ramos´.


Figure 14. ´Alina´.


Figure 15. ´Carmen´.

Flowering and harvest

Table 2 presents the dates of flowering and harvest of the ten varieties of quenepa used in this study. The time between flowering and harvest for the quenepa is approximately three months. Flowering occurred during the months of April and May and harvest during July to September. The data agree with that reported by Cruz and Torres, 2002. The ´Carmen´ exhibited the longest period of 103 days from flowering to harvest. ´Perfa´ exhibited the shortest period of 84 days from flowering to harvest.

Table 2. Quenepa flowering and harvest times.

Variety	Flowering	Harvest	Days	Flowering	Harvest	Days	Average (days)	Location
Pf	04/19/05	07/13/05	85	05/25/06	08/16/06	83	84	Cabo Rojo
JP	04/19/05	07/13/05	85	05/04/06	08/16/06	104	94.5	Cabo Rojo
Fe	04/26/05	07/20/05	85	05/04/06	08/29/06	117	101	Sabana Grande
Sm	04/15/05	07/20/05	96	04/20/06	07/07/06	78	87	Juana Diaz
Sa	05/10/05	08/03/05	85	04/20/06	07/24/06	95	90	Juana Diaz
Ma	04/15/05	08/03/05	110	05/04/06	07/18/06	75	92.5	Juana Diaz
Cu	04/26/05	08/03/05	99	05/11/06	08/02/06	83	91	Peñuelas
CR	04/26/05	08/03/05	99	05/25/06	08/22/06	89	94	Peñuelas
Al	04/26/05	08/17/05	113	05/04/06	07/24/06	81	97	Ponce
C	05/13/05	08/24/05	103	05/25/06	09/06/06	104	103.5	Boqueron

(Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Texture analysis

Figure 16 shows the force necessary to rupture pulp, for ten varieties of quenepa. There were significant differences in texture ($p<0.0001$) mainly for the varieties ´Alina´, ´Carmen´, ´Sasa´, and ´José Pabón´ which obtained the lowest rupture values of 15.19, 15.27, 15.46, 15.50 gf respectively. Varieties ´César Ramos´ and ´Las Cuevas´ obtained the highest values of rupture force, 31.17gf. The value of texture, could be indicator of pulp adherence and firmness, where, 'Cesar Ramos' and 'Cuevas' had pulp strongest and varieties as 'José Pabón', 'Sasa', 'Carmen' and 'Alina' less stronger.

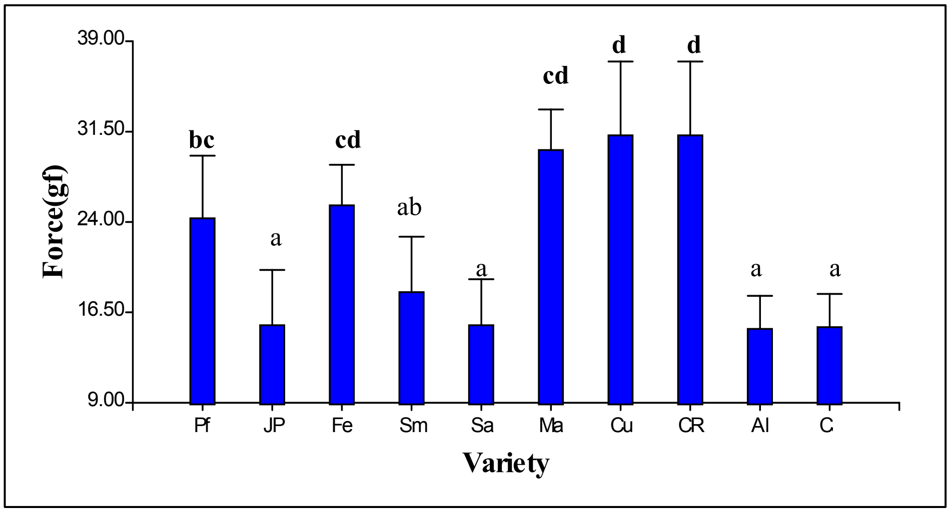

Figure 16. Force necessary for rupture of pulp in ten varieties of quenepa. Different letters indicate significant difference. (p< = 0.05).(Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Weight of fruit, seed and pulp

Table 3 shows the means of weight of fruit, pulp, peel, seed and percent of pulp as extracted by chemical method. An ANOVA test indicated significant differences ($p<0.0001$) for fruit weight and pulp percentage, but not for peel, seed or pulp weight. ´Doña Fela´ 8.7 g and ´Las Cuevas´ 9.8 g had the smallest weight and ´Perfa´ 23.3 g had a largest weight, but, ´Perfa´ 38.2% had a lowest percent of pulp and ´César Ramos´ 53.2% had a highest percent of pulp. Campbell (1972) in (Morton, 1987) and Jackson (1967) reported percentage of pulp in a range of 46.6 % to 55%. This is comparable with results obtained in this research (38% to 53%)

Table 3. Means of weight for ten varieties of quenepa (*Melicoccus bijugatus* Jacq.) and percent of pulp obtained by chemical method.

Variety	Wfruit	W peel	Wseed	Wpulp	%pulp
Pf	23.3 ± 2.4 g **	8.8 ± 1.2	5.4 ± 0.6	8.9 ± 1.3	38.2 ± 3.3 a *
JP	21.2 ± 2.7 f	5.3 ± 0.9	5.0 ± 0.8	10.7 ± 1.2	50.5 ± 2.5 de
Fe	8.7 ± 0.9 a *	1.7 ± 0.2	2.5 ± 0.3	4.5 ± 0.6	51.7 ± 2.8 ef
Ma	13.2 ± 1.6 b	3.9 ± 0.7	3.7 ± 0.4	5.5 ± 1.0	42.1 ± 2.3 b
Sa	14.6 ± 1.3 bc	4.0 ± 0.4	4.5 ± 0.5	6.2 ± 0.6	42.2 ± 2.2 b
Sm	14.9 ± 1.8 bc	4.1 ± 0.6	3.5 ± 0.6	7.3 ± 0.9	48.7 ± 1.8 d
Cu	9.8 ± 1.7 a *	3.1 ± 0.6	2.7 ± 0.5	4.0 ± 0.7	40.5 ± 1.9 ab
CR	15.6 ± 2.5 cd	3.7 ± 0.8	3.5 ± 0.5	8.3 ± 1.5	53.2 ± 3.2 f **
Al	17.1 ± 3.5 d	3.6 ± 0.8	4.7 ± 1.1	8.8 ± 1.8	51.4 ± 2.8 ef
C	19.4 ± 1.6 e	5.3 ± 0.9	5.2 ± 0.5	8.3 ± 0.9	46.2 ± 3.9 c

* Lowest value ** Highest value.

Different letters indicate significant difference. (p< = 0.05). (Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Extraction and adherence of the pulp by mechanical methods

The amount of pulp determined by mechanical extraction for the ten varieties (Table 4) ranged from 25.9 to 53.1 %. In this case, data was submitted to an analysis of variance by ANOVA ($p<0.0001$). ´César Ramos´ with method 2 demonstrated the highest percent of pulp, while in method 3 ´Las Cuevas´ had the lowest percent of pulp. Nevertheless, the variety with the most effective pulp extraction were ´José Pabón´ and ´César Ramos´ with an average of 45.2%, and 42.5% and the less effective were ´Martínez´, ´Las Cuevas´ and ´Alina´ (Al) with an average of 32.3 %, 33.7%, and 33.4% of pulp, respectively. By comparison, method 2 extracted more pulp (42%) than method 1 (37.5%) or method 3 (36.3%).

Table 4. Quantity of pulp extracted by three methods for ten varieties of quenepa (*Melicoccus bijugatus* Jacq.)

Variety	% Pulp			
	Method 1	**Method 2**	**Method 3**	**Average by variety**
Pf	41.7 ± 2.8 ^{ghijkl}	33.4 ± 1.5 ^{bcde}	32.8 ± 3.9 ^{bcd}	36.0 ± 5.0 ^{ab}
JP	38.8 ± 2.7 ^{defghij}	49.1 ± 0.9 ^{mn}	47.5 ± 1.3 ^{lmn}	45.2 ± 5.0 ^{d}
Fe	39.4 ± 4.2 ^{efghij}	43.6 ± 3.3 ^{ijklm}	43.1 ± 2.6 ^{hijklm}	42.0 ± 3.6 ^{bcd}
Sm	39.6 ± 2.7 ^{fghijk}	45.6 ± 0.8 ^{klm}	44.6 ± 0.2 ^{jklm}	43.3 ± 3.1 ^{cd}
Sa	37.1 ± 0.8 ^{defgh}	37.7 ± 1.8 ^{defghi}	36.2 ± 0.4 ^{defg}	37.0 ± 1.2 ^{abc}
Ma	34.8 ± 2.0 ^{cdef}	34.4 ± 0.4 ^{cdef}	27.6 ± 1.2 ^{ab}	32.3 ± 3.7 ^{a}
Cu	38.0 ± 0.5 ^{defghi}	37.1 ± 0.9 ^{defgh}	25.9 ± 1.1 ^{a}	33.7 ± 5.9 ^{a}
CR	37.6 ± 2.2 ^{defghi}	53.1 ± 1.1 ^{n}	36.9 ± 0.6 ^{defg}	42.5 ± 8.0 ^{cd}
Al	28.9 ± 0.3 ^{abc}	41.9 ± 2.4 ^{ghijkl}	29.3 ± 1.3 ^{abc}	33.4 ± 6.5 ^{a}
C	38.7 ± 0.6 ^{defghij}	44.3 ± 0.7 ^{jklm}	39.2 ± 0.6 ^{efghij}	40.7 ± 2.7 ^{bcd}
Average by method	37.5 ± 3.9 ^{a}	42.0 ± 6.3 ^{b}	36.3 ± 7.3 ^{a}	

Different letters indicate significant difference. ($p< = 0.05$). (Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Table 5 shows the pressure required to remove all the pulp using the vacuum pump method. This determination was used as an indicator of pulp adherence. The variety ´Sasa´ and ´Carmen´ required the lowest pressure of 3.4 PSI and 3.6 PSI respectively. ´César Ramos´, ´Perfa´ and ´Las Cuevas´ required the highest pressure of 12.0, 11.6 and 11.5 PSI, respectively. Pulp from ´Sasa´ and ´Carmen´ varieties adhered less strongly to the seed, and pulp from ´César Ramos´, ´Perfa´ and ´Las Cuevas´ were strongly attached to the seed. According to the data there was no relationship between pulp adherence and quantity of pulp extracted.

Table 5. Pulp adherence as determined by vacuum pump method

Variety	Pressure (PSI)
Pf	11.6 ± 0.8 de **
JP	8.7 ± 1.2 b
Fe	9.2 ± 0.6 bc
Sm	7.7 ± 0.7 b
Sa	3.4 ± 0.9 a*
Ma	9.3 ± 0.4 bcd
Cu	11.5 ± 1.5 cde**
CR	12.0 ± 0.3 e**
Al	7.9 ± 0.9 b
C	3.6 ± 0.3 a*

* Lowest pressure **Highest pressure

Different letters indicate significant difference. (p< = 0.05).
(Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Table 6 shows percentage of pulp by variety, by the mechanical methods used in this study as compared to chemical extraction.

In this comparison, the average mechanical pulp extracted was 38.6% and the chemical extraction was 46.5%. On the average mechanical extraction was 83% as effective as chemical extraction. On the other hand, the efficiency by method (Table 7) was calculated based on the average of percent pulp as presented in table 4 compared to the yield obtained by the chemical method. The more effective method was Method 2 which had an effectiveness of 90.3%.

Table 6. Efficiency of mechanical methods compared to the chemical method.

Variety	% pulp av. by variety (Extraction methods)	% pulp (Chem. Extraction)	% yield
Pf	36.0 ± 5.0	38.2 ± 3.3	94.2
JP	45.2 ± 5.0	50.5 ± 2.5	89.5
Fe	42.0 ± 3.6	51.7 ± 2.8	81.2
Sm	43.3 ± 3.1	42.1 ± 2.3	102.9
Sa	37.0 ± 1.2	42.2 ± 2.2	87.7
Ma	32.3 ± 3.7	48.7 ± 1.8	66.3
Cu	33.7 ± 5.9	40.5 ± 1.9	83.2
CR	42.5 ± 8.0	53.2 ± 3.2	79.9
Al	33.4 ± 6.5	51.4 ± 2.8	65.0
C.	40.7 ± 2.7	46.2 ± 3.9	88.1
Average	**38.6**	**46.5**	**83.8**

(Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Table 7. Extraction efficiency by method

Method	Effectiveness (%)
1	80.6
2	90.3
3	78.1

Effect of storage at 4°C on pulp adherence

´Sasa´ and ´Martínez´ were used for determine of the effect of storage on pulp adherence. An ANOVA analysis determined significant differences ($p<0.0001$) in changes of adherence depending on the variety, but no significant differences ($p = 0.3511$) for days of storage. Storing fruit for up to 16 days did not effect pulp adherence according to the assay method used in this study.

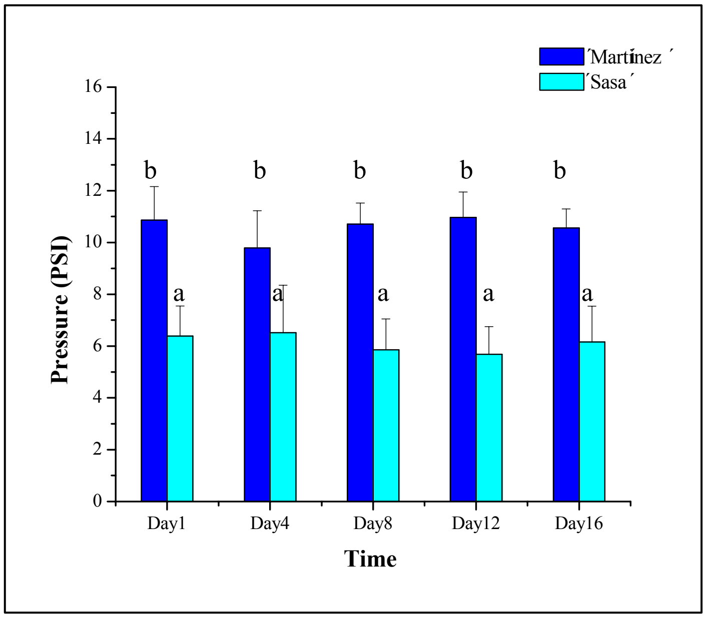

Figure 17. Adherence during storage at 4°C of two varieties ´Martínez´ and ´Sasa´. Different letters indicate significant difference. ($p <= 0.05$).

Color

Color is a parameter used to determine food quality. Pulp color is measured with a colorimeter MiniScan Hunter Lab, using values of **L**, **a**, and **b** (Figure 18). The **L** value ranges from 0-100 where 0 is given to dark colors (black) and 100 to light colors (white). The **a** value ranges from +100 to -80, with positive values given to reds and negatives values to greens. And **b** ranges from +70 to -80 where positives values are given to yellows, and negative values to blues. According to the statistical analysis, significant differences in colors were found in parameters L, a, b. Parameter L ($p<0.0001$) showed a differences in color intensity from dark to light, ´Sotomayor´, ´Alina´, ´Martínez´, ´Las

Cuevas´, ´Sasa´, ´Perfa´ and ´Doña Fela´ had darker pulp, while ´Carmen´ (CJ), ´César Ramos´ and ´José Pabón´ had lighter colored pulp.

Parameter **a,** presents a significant difference in tones of red between varieties ($p < 0.0001$), ´César Ramos´ and ´José Pabón´ are less red in tone compared to ´Sotomayor´ and ´Alina´, which had more intensity of red.

In parameter **b**, differences is seen ($p < 0.0001$) in the intensity of yellow, where ´Las Cuevas´, ´Perfa´, ´César Ramos´ and ´Sasa´, have a low yellow value, and the others varieties had more intensity for this color, however, the variety with more yellow intensity was ´Alina´.

The relation between values a and b, show, that ´César Ramos´, ´José Pabón´ and ´Carmen´ were less yellow, and ´Alina´, ´Sotomayor´ and ´Doña Fela´ were more yellow.

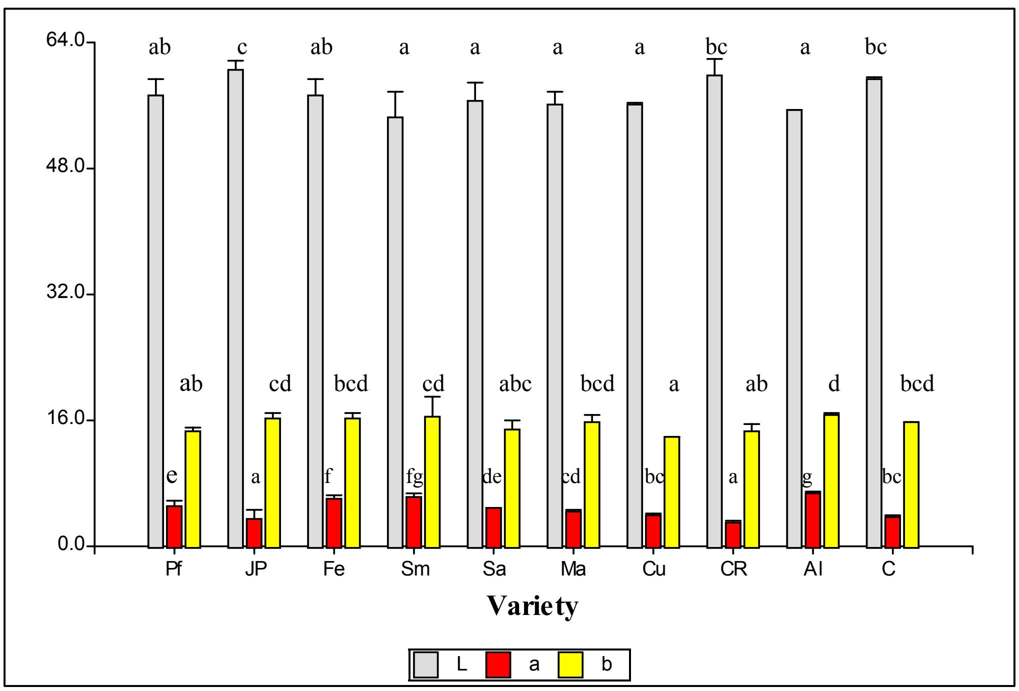

Figure 18. Color measurement of quenepa varieties by extraction method.
Different letters indicate significant difference. ($p <= 0.05$). (Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Organic acids analysis

Table 8 shows the predominant acids by variety. These results are an average of acids found in the three extraction methods. The major non volatile organic acid in quenepa was citric acid (except for 'Martínez' which presents a similar value for acetic acid). Malic, succinic and acetic acid are minor constituents. Oxalic acid is present but in small amounts. the first peak corresponds to the mobile phase.

Table 8. Predominant organic acids in ten varieties of quenepa extracted by three methods.

Variety	% acid			
	Citric	**Malic**	**Succinic**	**Acetic**
Pf	0.90 ± 0.20 ^{b}	0.18 ± 0.04 ^{d}	0.09 ± 0.02 ^{ab}	0.44 ± 0.21 ^{d}
JP	1.18 ± 0.03 ^{cd}	0.31 ± 0.01 ^{e}	0.16 ± 0.02 ^{c}	0.22 ± 0.02 ^{bc}
Fe	1.02 ± 0.14 ^{bc}	0.12 ± 0.08 ^{ab}	0.08 ± 0.04 ^{ab}	0.35 ± 0.07 ^{cd}
Sm	0.55 ± 0.04 ^{a}	0.13 ± 0.02 ^{abcd}	0.07 ± 0.01 ^{ab}	0.02 ± 0.03 ^{a}
Sa	0.98 ± 0.19 ^{b}	0.16 ± 0.02 ^{bcd}	0.11 ± 0.02 ^{b}	0.39 ± 0.31 ^{cd}
Ma	0.67 ± 0.05 ^{a}	0.16 ± 0.01 ^{cd}	0.08 ± 0.03 ^{ab}	0.68 ± 0.06 ^{e}
Cu	1.04 ± 0.06 ^{bcd}	0.10 ± 0.01 ^{a}	0.06 ± 0.00 ^{a}	0.24 ± 0.05 ^{bc}
CR	1.23 ± 0.23 ^{d}	0.12 ± 0.01 ^{abc}	0.16 ± 0.04 ^{c}	0.21 ± 0.08 ^{abc}
Al	1.48 ± 0.05 ^{e}	0.13 ± 0.02 ^{abc}	0.11 ± 0.01 ^{b}	0.30 ± 0.01 ^{bcd}
C	1.06 ± 0.06 ^{bcd}	0.13 ± 0.03 ^{abcd}	0.07 ± 0.01 ^{a}	0.13 ± 0.01 ^{ab}

Different letters indicate significant difference. ($p< = 0.05$). (Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Perez et al. (1997) present a comparison between fruits such as peach, apple, kiwi and banana. The citric acid content of these fruits was reported 197.2, trace, 985, and 359 mg/100g, respectively. Malic acid was found with values of 282.4, 412.2, 190.8, and 289.4 mg/100g, respectively; others were found in lower content. In addition, the ascorbic acid was not detected in peach, apple and banana.

These authors describe that the ascorbic acid is the most affected compound during the processing of fruits and vegetables. This instability of ascorbic acid is mainly due to its tendency to react with oxygen, forming dehydroascorbic acid and further degradation products.

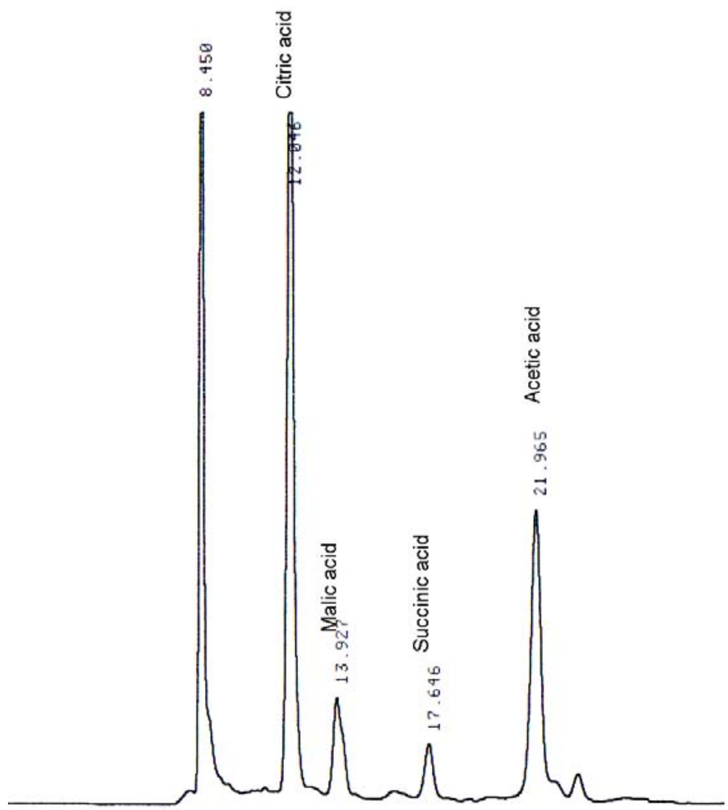

Figure 19. Chromatogram of HPLC for organic acids in quenepa (*Melicoccus bijugatus* Jacq.) variety ´Martínez´ (Ma).

Significant differences (P< 0.0001) were found between varieties. In the determination of citric acid, ´Sotomayor´ and ´Martínez´ had the smallest content of this acid and ´Alina´ had the highest value.

For malic acid ´Las Cuevas´ had the lowest quantity and ´José Pabón´ had the highest content; for succinic acid ´Las Cuevas´ and ´Carmen´ had smallest content, ´César Ramos´ and ´José Pabón´ had highest acid content. In the case for acetic acid ´Sotomayor´

was the lowest value and ´Martínez´ was a highest value. Acetic acid is a volatile acid, so its concentration can be affected by the extraction method. Or when the fruit is ripening. The acids content is related with the titratable acidity of the pulp. Each acid was identified by its retention time in comparison with standard solutions of pure acids (Hyoung, 1993)

pH determination

pH is an indicator of acidity in a fruit (Table 9). In this study the lowest pH (3.23) was seen in ´Carmen´ variety and the highest pH (3.73) in ´Las Cuevas´. These values can sometimes depend on soil and environmental factors. The ANOVA found significant differences ($p<0.0001$) between ´Carmen´, with the lowest value, and ´Las Cuevas´, with the highest value.

Table 9. pH for ten varieties of quenepa

Variety	pH
Pf	3.70 ± 0.01^{g}
JP	3.41 ± 0.01^{c}
Fe	3.36 ± 0.02^{b}
Sm	3.72 ± 0.01^{g}
Sa	3.66 ± 0.01^{f}
Ma	3.62 ± 0.01^{e}
Cu	3.73 ± 0.02^{g}
CR	3.38 ± 0.01^{bc}
Al	3.53 ± 0.01^{d}
C	3.23 ± 0.01^{a}

Different letters indicate significant difference. ($p< = 0.05$).
(Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, Ca: ´Carmen´).

Size

The ten varieties present differences in diameter, length and spherical relation (Table 10). The largest diameter was ´Alina´ and the smallest diameter was ´César Ramos´. The greatest length was for ´Sasa´ and the smallest value was ´Las Cuevas´. The volume was calculated by following formula:

$$V = 4/3\ \pi\ r^3 \qquad \text{(Eq. 9)}$$

Where, the radius (**r)** was calculated from an average of length and diameter of the fruit. The results obtained show that ´´José Pabón´´, ´Martínez´, ´Sasa´, ´Perfa´, ´Alina´ and ´Sotomayor´ present the highest volume and the smallest volume were ´Las Cuevas´ and ´César Ramos´.

Another parameter evaluated was the spherical relation (L/D) where the smallest value was 1.12 for ´Las Cuevas´ and the largest was ´Sasa´ with 1.41. This relation indicates whether the form is ovoid or spherical. If this value is 1 the form is spherical. Size can be determined also by weight as presented in Table 3.

Table 10. Diameter, length, volume and spherical relation for ten varieties of quenepa

Variety	Diameter (cm)	Length (cm)	Volume (cm^3)	Spherical Relation
Pf	2.86 ± 0.17 [c]	3.94 ± 0.21 [de]	0.02 ± 0.00 [d]	1.38 ± 0.09 [ef]
JP	2.93 ± 0.10 [cd]	3.98 ± 0.20 [e]	0.02 ± 0.00 [d]	1.36 ± 0.05 [def]
Fe	2.72 ± 0.11 [b]	3.47 ± 0.16 [b]	0.02 ± 0.00 [b]	1.28 ± 0.05 [bcd]
Sm	2.88 ± 0.08 [c]	3.54 ± 0.20 [b]	0.02 ± 0.00 [bcd]	1.23 ± 0.06 [b]
Sa	2.86 ± 0.17 [c]	4.03 ± 0.25 [e]	0.02 ± 0.00 [d]	1.41 ± 0.07 [f]
Ma	2.96 ± 0.22 [cd]	3.87 ± 0.29 [de]	0.02 ± 0.00 [d]	1.31 ± 0.10 [cde]
Cu	2.71 ± 0.10 [b]	3.05 ± 0.15 [a]	0.01 ± 0.00 [a]	1.12 ± 0.03 [a]
CR	2.54 ± 0.16 [a]	3.21 ± 0.34 [a]	0.01 ± 0.00 [a]	1.26 ± 0.07 [bc]
Al	3.05 ± 0.14 [d]	3.76 ± 0.23 [cd]	0.02 ± 0.00 [cd]	1.23 ± 0.07 [b]
C	2.70 ± 0.21 [b]	3.61 ± 0.40 [bc]	0.02 ± 0.00 [bc]	1.35 ± 0.21 [def]

Different letters indicate significant difference. ($p <= 0.05$). (Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Figure 20. Sizes of quenepa fruits (*Melicoccus bijugatus* Jacq.) [Top, left to right: ´Perfa´, ´José Pabón´, ´Doña Fela´ and ´Martínez´. Bottom, Left to right: ´Sasa´, ´Las Cuevas´ and ´Alina´].

Total soluble solid

Table 11 shows the total soluble solids measured with two instruments. The first measure was taken with a hand refractometer and the second with an Abbe refractometer measuring a Refraction Index (RI) value. The RI value was converted according to specific tables of the AOAC (See Appendix).

The ANOVA determined significant differences in total soluble solids content, ´Alina´ and ´César Ramos´ have less soluble solids while ´Martínez´ has the highest value for soluble solids.

Table 11. Means of total soluble solids for quenepa varieties.

Variety	° Brix	RI	°Brix ct
Pf	20.53 ± 0.12 ^{bc}	1.3660 ± 0.0005	21.62 ± 0.30 ^{de}
JP	20.47 ± 0.23 ^{bc}	1.3653 ± 0.0003	21.20 ± 0.17 ^{cde}
Fe	20.00 ± 0.20 ^{b}	1.3641 ± 0.0007	20.47 ± 0.42 ^{bcd}
Sm	20.47 ± 0.81 ^{bc}	1.3660 ± 0.0005	21.60 ± 0.30 ^{de}
Sa	20.07 ± 0.90 ^{b}	1.3633 ± 0.0020	20.00 ± 1.22 ^{bc}
Ma	21.67 ± 0.12 ^{c}	1.3670 ± 0.0000	22.12 ± 0.00 ^{e}
Cu	19.33 ± 0.31 ^{b}	1.3627 ± 0.0003	19.60 ± 0.17 ^{b}
CR	16.80 ± 0.20 ^{a}	1.3587 ± 0.0006	17.16 ± 0.36 ^{a}
Al	16.67 ± 0.23 ^{a}	1.3587 ± 0.0003	17.21 ± 0.13 ^{a}
C	20.40 ± 0.53 ^{bc}	1.3657 ± 0.0003	21.48 ± 0.17 ^{de}

ct.°Brix according to conversion table.

Different letters indicate significant difference. ($p< = 0.05$). (Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Titratable acidity

Table 12 shows the values of titratable acidity in ten varieties of fruit. The ANOVA found significant differences (p<0.0001), between varieties; ´Sotomayor´ (Sm) and ´Martínez´ (Ma) are less acidic and ´César Ramos´ (CR), ´Alina´ (Al) and ´José Pabón´ (JP) were the most acidic.

Table 12 Titratable acidity (reported g of citric acid per / 100 g).

Variety	g citric ac / 100 g fruit
Pf	1.08 ± 0.03 [b]
JP	1.87 ± 0.07 [e]
Fe	1.47 ± 0.56 [c]
Sm	0.88 ± 0.01 [a]
Sa	1.21 ± 0.03 [b]
Ma	0.97 ± 0.02 [a]
Cu	1.09 ± 0.00 [c]
CR	1.88 ± 0.05 [e]
Al	1.38 ± 0.04 [e]
C	1.09 ± 0.01 [d]

Different letters indicate significant difference. (p< = 0.05).
(Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

Harvest index

Table 13 presents values of harvest index calculated from the results obtained ANOVA was applied to the data and significant differences (P< 0.0001) were found. ´César Ramos´ and ´Alina´ presented the lowest value in comparison with ´Martínez´ and ´Sotomayor´. The differences may occur of the genetic variability of cultivars or because of variation in the degree of ripeness of the cultivars. Cruz and Torres (2002) established that the maturity index determination could be helpful in determining the best time to harvest because of the external green color of the fruit.

Table 13. Harvest index for ten varieties of quenepa (*Melicoccus bijugatus* Jacq.).

Variety	**Harvest index**
Pf	20.04 ± 0.84 [f]
JP	11.36 ± 0.35 [b]
Fe	14.48 ± 0.58 [c]
Sm	24.48 ± 0.56 [g]
Sa	16.51 ± 1.30 [d]
Ma	23.15 ± 0.56 [g]
Cu	18.03 ± 0.15 [de]
CR	9.15 ± 0.31 [a]
Al	12.52 ± 0.36 [b]
C	19.67 ± 0.28 [ef]

Different letters indicate significant difference. (p< = 0.05).
(Pf: ´Perfa´, JP: ´José Pabón´, Fe: ´Doña Fela´, Sm: ´Sotomayor´, Sa: ´Sasa´, Ma: ´Martínez´, Cu: ´Las Cuevas´, CR: ´César Ramos´, Al: ´Alina´, C: ´Carmen´).

CONCLUSIONS

According to the results variation exists in the adherence of pulp in quenepa, where ´Sasa´ and ´Carmen´, had pulp that was less adherent to the seed and ´César Ramos´, ´Las Cuevas´ and ´Perfa´ were most adherent. The adherence for quenepa pulp did not change with storage at 4°C.

Quenepa cultivars have differences in pulp color, total soluble solids, pH and total acidity. ´Alina´, ´Sotomayor´ and ´Doña Fela´ presented the most intense yellow color. ´Martínez´, ´Sotomayor´, ´Carmen´, ´Perfa´ and ´José Pabón´ had greater soluble solids. The most acidic variety was ´César Ramos´.

There were differences in organic acid content by variety, and the predominant organic acid was citric acid, except ‘Martínez’ that present the same quantity for acetic acid. ‘Alina´ had the highest content of this acid, while ´Sotomayor´ and ´Martínez´ had a lower content.

There were significant differences in fruit size for all varieties. ´José Pabón´, ´Martínez´, ´Sasa´, ´Perfa´, ´Alina´ and ´Sotomayor´ had the largest volume, while ´Las Cuevas´ and ´César Ramos´ had the smallest volume.

The percent of pulp ranged between 38-53% and was not correlated with weight or pulp adherence.

These results established an initial framework upon which additional information based on agronomic variability could ascertain a better differentiation of the quenepa cultivars used in this study.

RECOMMENDATIONS

- Further studies in postharvest physiology and packaging to improve shelf life.
- Develop methods like harvest index to optimize harvesting time and therefore fruit quality.
- Develop methods that use enzymes to optimize the extraction and yield of pulp even if the pulp has a strong adherence to the seed.

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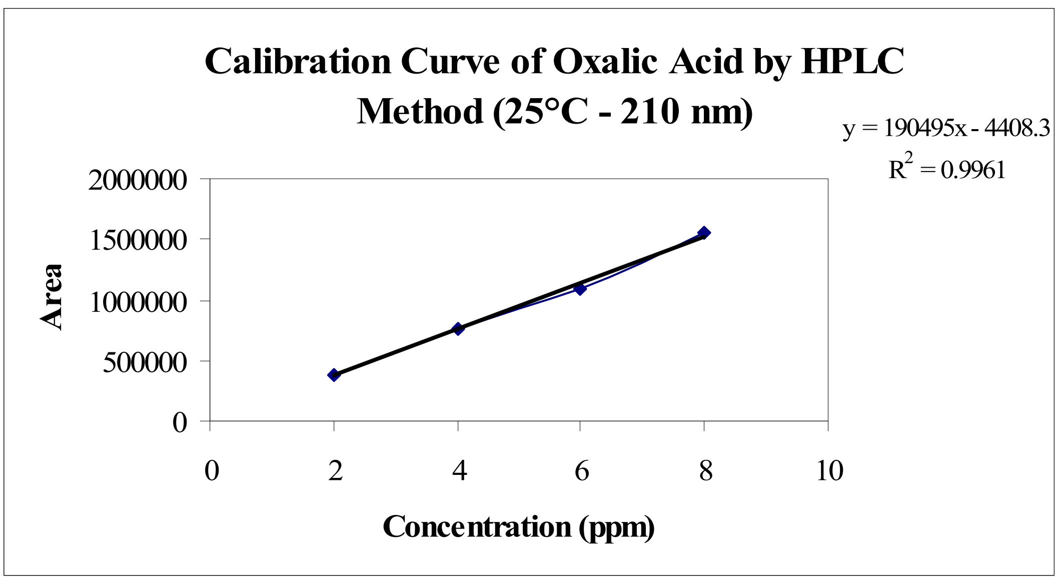
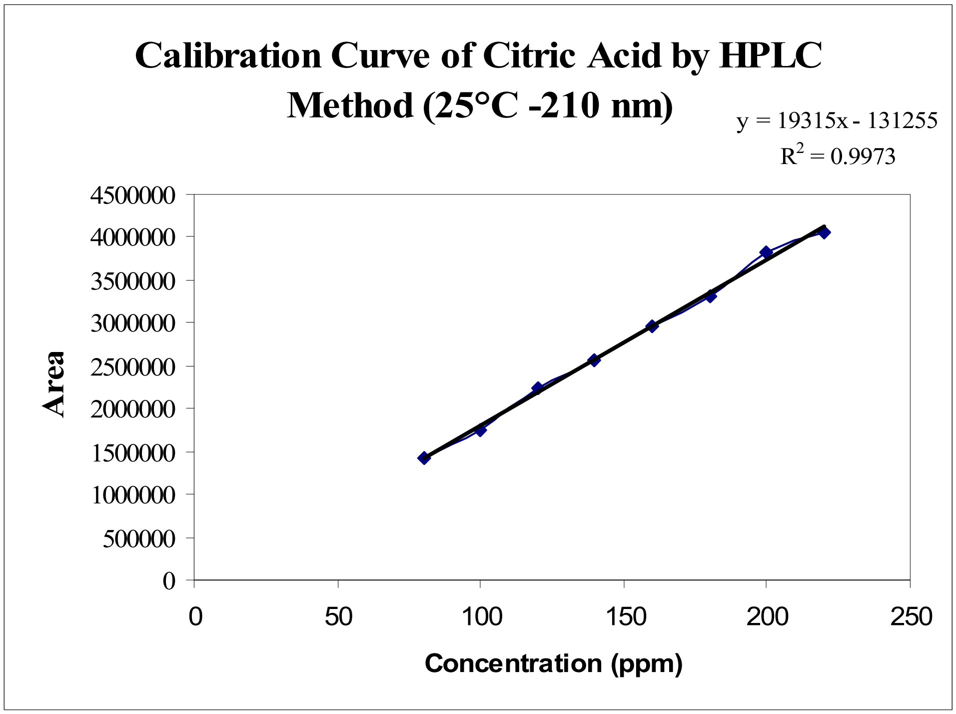
APPENDIX

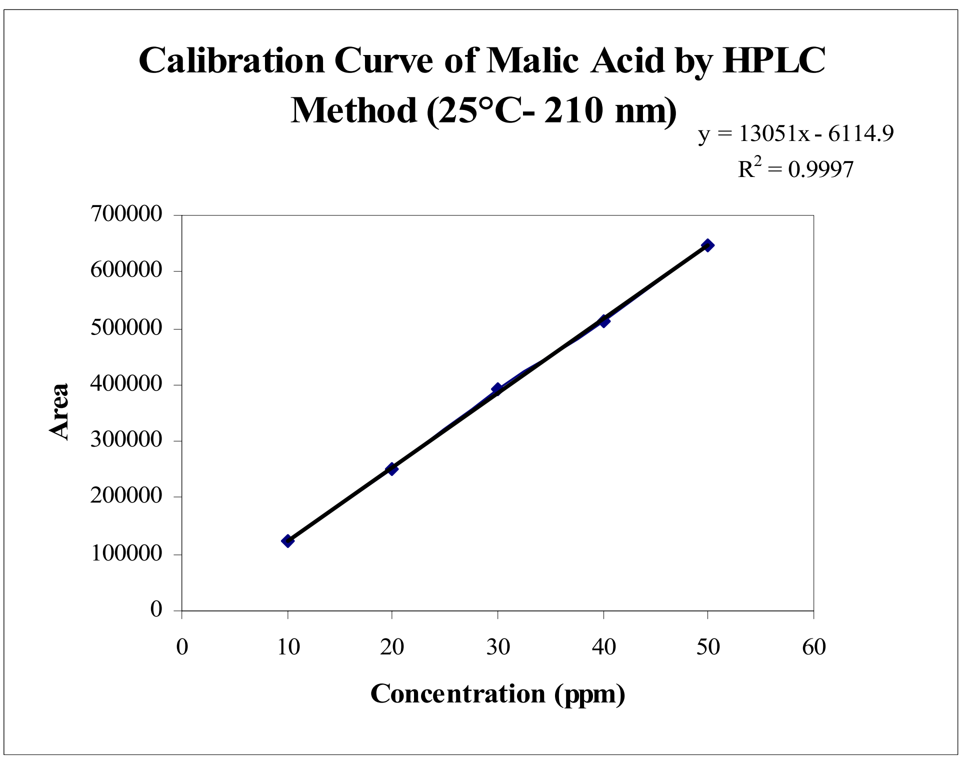
Appendix 1. Effect of pulp adherence in storage

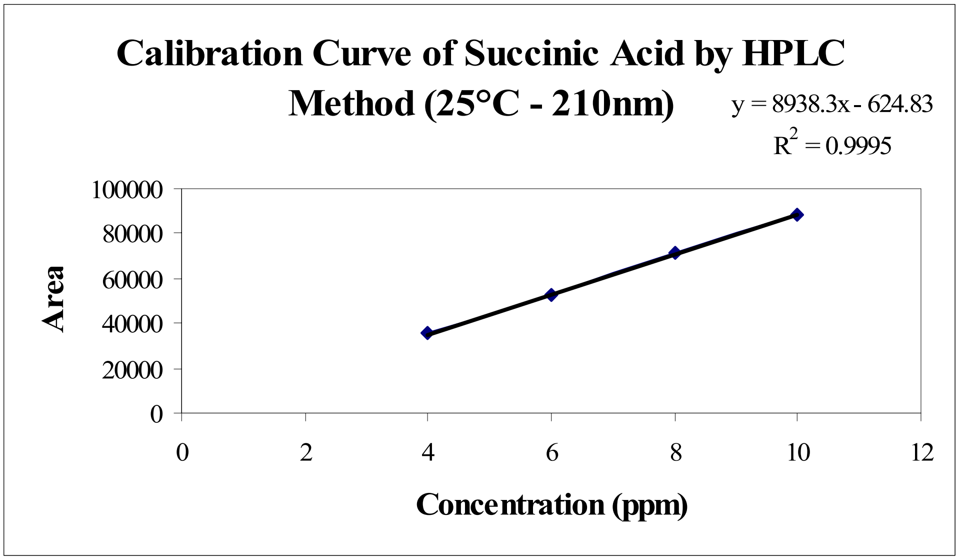
Day	Pressure (PSI)	
	Martinez	Sasa
1	10.9 ± 1.3	6.4 ± 1.2
4	9.8 ± 1.4	6.5 ± 1.8
8	10.7 ± 0.8	5.9 ± 1.2
12	11.0 ± 1.0	5.7 ± 1.1
16	10.6 ± 0.7	6.2 ± 1.4
20	10.4 ± 1.0	-

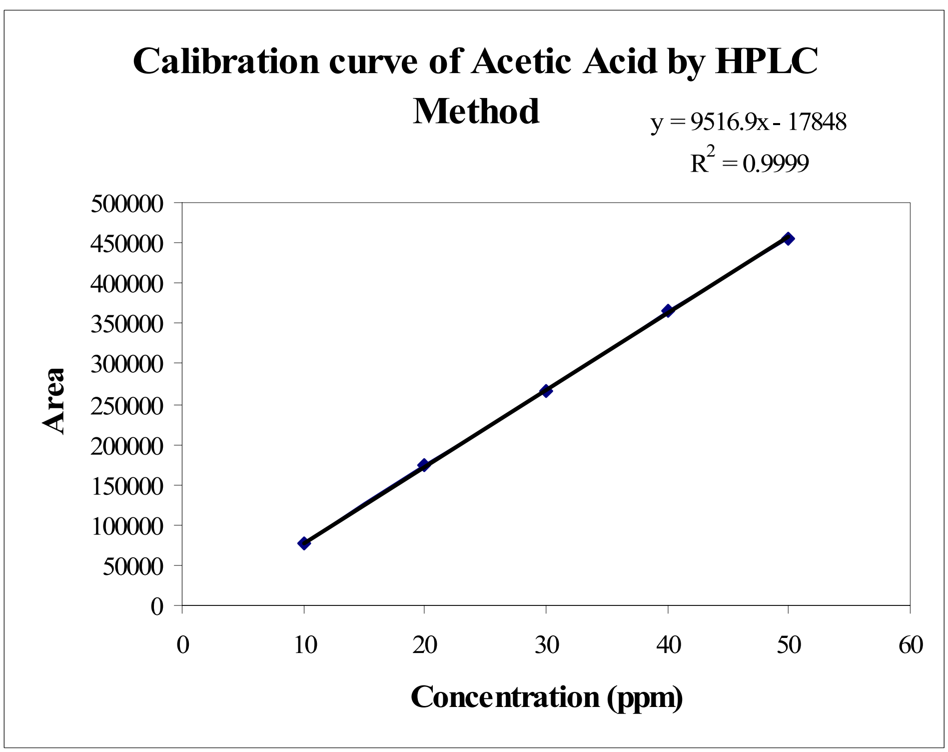
Appendix 2. Calibration curves of organic acids (HPLC method)




Calibration Curve of Citric Acid by HPLC Method (25°C -210 nm)
y = 19315x - 131255
R2 = 0.9973
Area
4500000
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
0
50
100
150
200
250
Concentration (ppm)


Calibration Curve of Malic Acid by HPLC Method (25°C- 210 nm)
y = 13051x - 6114.9
R2 = 0.9997
Area
700000
600000
500000
400000
300000
200000
100000
0
0
10
20
30
40
50
60
Concentration (ppm)


Calibration Curve of Succinic Acid by HPLC Method (25°C - 210nm)
y = 8938.3x - 624.83
R2 = 0.9995
100000
80000
60000
40000
20000
0
Area
0
2
4
6
8
10
12
Concentration (ppm)


Calibration curve of Acetic Acid by HPLC Method
y = 9516.9x - 17848
R2 = 0.9999
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Area
0
10
20
30
40
50
60
Concentration (ppm)

Appendix 3. Relation a/b for determined of color in ten varieties of quenepa

Variety	**Relation a/b**
Pf	0.35 ± 0.05 de
JP	0.22 ± 0.05 a
Fe	0.37 ± 0.03 def
Sm	0.39 ± 0.05 ef
Sa	0.33 ± 0.03 cd
Ma	0.28 ± 0.02 bc
Cu	0.29 ± 0.01 bc
CR	0.21 ± 0.01 a
Al	0.41 ± 0.01 f
CJ	0.24 ± 0.01 ab

Appendix 4. Statistical Analysis

4.1. Analysis of variance for texture

Variable	N	R²	R²Aj	CV
Force(gf)	100	0.72	0.69	19.92

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	4411.90	9	490.21	25.14	<0.0001
Variety	4411.90	9	490.21	25.14	<0.0001
Error	1754.65	90	19.50		
Total	6166.55	99			

Test: Tukey Alfa: 0.05 DMS: 6.42710

Error: 19.4961 gl: 90

Variety	Medias	n				
Al	15.19	10	A			
CJ	15.27	10	A			
Sa	15.46	10	A			
JP	15.50	10	A			
Sm	18.13	10	A	B		
Pf	24.37	10		B	C	
Fe	25.42	10			C	D
Ma	30.02	10			C	D
CR	31.17	10				D
Cu	31.17	10				D

Letras distintas indican diferencias significativas(p<=0.05)

4.2. Analysis of variance for weight

Variable	N	R^2	R^2Aj	CV
W fruit	300	0.82	0.81	13.52

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	5879.86	9	653.32	143.36	<0.0001
Variety	5879.86	9	653.32	143.36	<0.0001
Error	1321.55	290	4.56		
Total	7201.41	299			

Test: Tukey Alfa: 0.05 DMS: 1.78816

Error: 4.5571 gl: 290

Variety	Medias	n							
Fe	8.74	30	A						
Cu	9.80	30	A						
Ma	13.19	30		B					
Sa	14.63	30		B	C				
Sm	14.93	30		B	C				
CR	15.55	30			C	D			
Al	17.11	30				D			
CJ	19.43	30					E		
JP	21.22	30						F	
Pf	23.34	30							G

Letras distintas indican diferencias significativas(p<=0.05)

4.3. Analysis of variance for %pulp by method and variety

Variable	N	R^2	R^2Aj	CV
% Pulp	90	0.63	0.58	10.76

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	2319.97	11	210.91	12.23	<0.0001
Variety	1777.40	9	197.49	11.46	<0.0001
Method	542.57	2	271.28	15.74	<0.0001
Error	1344.75	78	17.24		
Total	3664.71	89			

Test: Tukey Alfa: 0.05 DMS: 6.39431

Error: 17.2403 gl: 78

Variety	Medias	n				
Ma	32.28	9	A			
Al	33.37	9	A			
Cu	33.65	9	A			
Pf	35.98	9	A	B		
Sa	36.98	9	A	B	C	
CJ	40.73	9		B	C	D
Fe	42.01	9		B	C	D
CR	42.54	9			C	D
Sm	43.25	9			C	D
JP	45.15	9				D

Letras distintas indican diferencias significativas(p<=0.05)

Test: Tukey Alfa: 0.05 DMS: 2.56684

Error: 17.2403 gl: 78

Method	Medias	n		
3.00	36.32	30	A	
1.00	37.47	30	A	
2.00	42.00	30		B

Letras distintas indican diferencias significativas(p<=0.05)

4.4. Analysis of variance for %pulp method * variety

Test: Tukey Alfa: 0.05 DMS: 6.02704

Error: 3.5176 gl: 60

Variety	Method	Medias	n														
Cu	3.00	25.93	3	A													
Ma	3.00	27.65	3	A	B												
Al	1.00	28.94	3	A	B	C											
Al	3.00	29.32	3	A	B	C											
Pf	3.00	32.83	3		B	C	D										
Pf	2.00	33.42	3		B	C	D	E									
Ma	2.00	34.42	3			C	D	E	F								
Ma	1.00	34.77	3			C	D	E	F								
Sa	3.00	36.19	3				D	E	F	G							
CR	3.00	36.93	3				D	E	F	G							
Cu	2.00	37.05	3				D	E	F	G	H						
Sa	1.00	37.07	3				D	E	F	G	H						
CR	1.00	37.58	3				D	E	F	G	H	I					
Sa	2.00	37.68	3				D	E	F	G	H	I					
Cu	1.00	37.98	3				D	E	F	G	H	I					
CJ	1.00	38.74	3				D	E	F	G	H	I	J				
JP	1.00	38.84	3				D	E	F	G	H	I	J				
CJ	3.00	39.15	3					E	F	G	H	I	J				
Fe	1.00	39.41	3					E	F	G	H	I	J				
Sm	1.00	39.64	3						F	G	H	I	J	K			
Pf	1.00	41.70	3							G	H	I	J	K	L		
Al	2.00	41.86	3							G	H	I	J	K	L		
Fe	3.00	43.05	3								H	I	J	K	L	M	
Fe	2.00	43.56	3									I	J	K	L	M	
CJ	2.00	44.31	3										J	K	L	M	
Sm	3.00	44.56	3										J	K	L	M	
Sm	2.00	45.56	3											K	L	M	
JP	3.00	47.55	3												L	M	N
JP	2.00	49.07	3													M	N
CR	2.00	53.11	3														N

Letras distintas indican diferencias significativas(p<=0.05)

4.5. Analysis of variance for pressure (adherence)

Variable	N	R^2	R^2Aj	CV
Pressure (PSI)	30	0.95	0.92	9.82

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	246.17	9	27.35	39.39	<0.0001
Variety	246.17	9	27.35	39.39	<0.0001
Error	13.89	20	0.69		
Total	260.06	29			

Test: Tukey Alfa: 0.05 DMS: 2.40939

Error: 0.6944 gl: 20

Variety	Medias	n					
Sa	3.44	3	A				
CJ	3.63	3	A				
Sm	7.72	3		B			
Al	7.86	3		B			
JP	8.68	3		B			
Fe	9.21	3		B	C		
Ma	9.33	3		B	C	D	
Cu	11.46	3			C	D	E
Pf	11.63	3				D	E
CR	11.95	3					E

Letras distintas indican diferencias significativas(p<=0.05)

4.6. Analysis of variance for effect of storage at 4°C on pulp adherence

Variable	N	R^2	R^2Aj	CV
Day 1	60	0.77	0.77	14.30

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1246.70	1	1246.70	197.65	<0.0001
Variety	1246.70	1	1246.70	197.65	<0.0001
Error	365.84	58	6.31		
Total	1612.55	59			

Test: Tukey Alfa: 0.05 DMS: 1.29857

Error: 6.3076 gl: 58

Variety	Medias	n		
Sa	13.00	30	A	
Ma	22.12	30		B

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2Aj	CV
Day 4	60	0.51	0.50	20.16

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	666.67	1	666.67	59.51	<0.0001
Variety	666.67	1	666.67	59.51	<0.0001
Error	649.73	58	11.20		
Total	1316.40	59			

Test: Tukey Alfa: 0.05 DMS: 1.73056

Error: 11.2023 gl: 58

Variety	Medias	n		
Sa	13.27	30	A	
Ma	19.93	30		B

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2 Aj	CV
Day 8	60	0.85	0.85	12.33

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1460.27	1	1460.27	337.88	<0.0001
Variety	1460.27	1	1460.27	337.88	<0.0001
Error	250.67	58	4.32		
Total	1710.93	59			

Test: Tukey Alfa: 0.05 DMS: 1.07490

Error: 4.3218 gl: 58

Variety	Medias	n		
Sa	11.93	30	A	
Ma	21.80	30		B

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2 Aj	CV
Day 12	60	0.87	0.87	12.30

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1738.82	1	1738.82	400.15	<0.0001
Variety	1738.82	1	1738.82	400.15	<0.0001
Error	252.03	58	4.35		
Total	1990.85	59			

Test: Tukey Alfa: 0.05 DMS: 1.07782

Error: 4.3454 gl: 58

Variety	Medias	n		
Sa	11.57	30	A	
Ma	22.33	30		B

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2 Aj	CV
Day 16	60	0.80	0.80	13.25

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1206.02	1	1206.02	237.14	<0.0001
Variety	1206.02	1	1206.02	237.14	<0.0001
Error	294.97	58	5.09		
Total	1500.98	59			

Test: Tukey Alfa: 0.05 DMS: 1.16602

Error: 5.0856 gl: 58

Variety	Medias	n		
Sa	12.53	30	A	
Ma	21.50	30		B

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2Aj	CV
Pres (PSI)	300	0.76	0.76	15.16

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1497.97	5	299.59	186.94	<0.0001
Variety	1490.84	1	1490.84	930.27	<0.0001
Day	7.13	4	1.78	1.11	0.3511
Error	471.16	294	1.60		
Total	1969.13	299			

Test: Tukey Alfa: 0.05 DMS: 0.29045

Error: 1.6026 gl: 294

Variety	Medias	n		
Sa	6.12	150	A	
Ma	10.58	150		B

Letras distintas indican diferencias significativas(p<=0.05)

Test: Tukey Alfa: 0.05 DMS: 0.64343

Error: 1.6026 gl: 294

Day	Medias	n	
4.00	8.15	60	A
8.00	8.28	60	A
12.00	8.33	60	A
16.00	8.36	60	A
1.00	8.62	60	A

Letras distintas indican diferencias significativas (p<=0.05)

4.7. Analysis of variance for color (Lab)

Variable	N	R^2	R^2Aj	CV
L	90	0.56	0.51	3.20

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	338.15	9	37.57	11.15	<0.0001
Variety	338.15	9	37.57	11.15	<0.0001
Error	269.46	80	3.37		
Total	607.61	89			

Test: Tukey Alfa: 0.05 DMS: 2.82449

Error: 3.3682 gl: 80

Variety	Medias	n			
Sm	54.54	9	A		
Al	55.41	9	A		
Ma	56.01	9	A		
Cu	56.14	9	A		
Sa	56.49	9	A		
Pf	57.22	9	A	B	
Fe	57.35	9	A	B	
CJ	59.47	9		B	C
CR	59.93	9		B	C
JP	60.63	9			C

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R²	R²Aj	CV
a	90	0.89	0.88	9.59

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	131.26	9	14.58	70.27	<0.0001
Variety	131.26	9	14.58	70.27	<0.0001
Error	16.60	80	0.21		
Total	147.87	89			

Test: Tukey Alfa: 0.05 DMS: 0.70114

Error: 0.2076 gl: 80

Variety	Medias	n							
CR	2.98	9	A						
JP	3.56	9	A	B					
CJ	3.74	9		B	C				
Cu	4.00	9		B	C				
Ma	4.32	9			C	D			
Sa	4.80	9				D	E		
Pf	5.06	9					E		
Fe	5.92	9						F	
Sm	6.31	9						F	G
Al	6.84	9							G

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R²	R²Aj	CV
b	90	0.45	0.39	6.90

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	74.55	9	8.28	7.28	<0.0001
Variety	74.55	9	8.28	7.28	<0.0001
Error	91.01	80	1.14		
Total	165.56	89			

Test: Tukey Alfa: 0.05 DMS: 1.64147

Error: 1.1376 gl: 80

Variety	Medias	n				
Cu	13.89	9	A			
Pf	14.50	9	A	B		
CR	14.52	9	A	B		
Sa	14.86	9	A	B	C	
Ma	15.66	9		B	C	D
CJ	15.68	9		B	C	D
Fe	16.14	9		B	C	D
JP	16.30	9			C	D
Sm	16.42	9			C	D
Al	16.67	9				D

Letras distintas indican diferencias significativas(p<=0.05)

4.8. Analysis of variance for organic acids

Variable	N	R^2	R^2Aj	CV
Citric acid (%)	90	0.82	0.80	12.57

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	5.81	9	0.65	39.89	<0.0001
Variety	5.81	9	0.65	39.89	<0.0001
Error	1.29	80	0.02		
Total	7.10	89			

Test: Tukey Alfa: 0.05 DMS: 0.19571

Error: 0.0162 gl: 80

Variety	Medias	n					
Sm	0.55	9	A				
Ma	0.67	9	A				
Pf	0.90	9		B			
Sa	0.98	9		B			
Fe	1.02	9		B	C		
Cu	1.04	9		B	C	D	
CJ	1.06	9		B	C	D	
JP	1.18	9			C	D	
CR	1.23	9				D	
Al	1.48	9					E

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2Aj	CV
Malic Acid(%)	90	0.80	0.78	19.42

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	0.28	9	0.03	35.28	<0.0001
Variety	0.28	9	0.03	35.28	<0.0001
Error	0.07	80	0.00		
Total	0.35	89			

Test: Tukey Alfa: 0.05 DMS: 0.04577

Error: 0.0009 gl: 80

Variety	Medias	n					
Cu	0.10	9	A				
Fe	0.12	9	A	B			
CR	0.12	9	A	B	C		
Al	0.13	9	A	B	C		
Sm	0.13	9	A	B	C	D	
CJ	0.14	9	A	B	C	D	
Sa	0.16	9		B	C	D	
Ma	0.16	9			C	D	
Pf	0.18	9				D	
JP	0.31	9					E

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2Aj	CV
Succinic acid(%)	90	0.72	0.68	22.75

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	0.10	9	0.01	22.43	<0.0001
Variety	0.10	9	0.01	22.43	<0.0001
Error	0.04	80	0.00		
Total	0.14	89			

Test: Tukey Alfa: 0.05 DMS: 0.03466

Error: 0.0005 gl: 80

Variety	Medias	n			
Cu	0.06	9	A		
CJ	0.07	9	A		
Sm	0.07	9	A	B	
Ma	0.08	9	A	B	
Fe	0.08	9	A	B	
Pf	0.09	9	A	B	
Al	0.11	9		B	
Sa	0.11	9		B	
CR	0.16	9			C
JP	0.16	9			C

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2Aj	CV
Acetic acid(%)	90	0.68	0.64	42.24

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	2.72	9	0.30	18.94	<0.0001
Variety	2.72	9	0.30	18.94	<0.0001
Error	1.27	80	0.02		
Total	3.99	89			

Test: Tukey Alfa: 0.05 DMS: 0.19424

Error: 0.0159 gl: 80

Variety	Medias	n					
Sm	0.02	9	A				
CJ	0.13	9	A	B			
CR	0.21	9	A	B	C		
JP	0.22	9		B	C		
Cu	0.24	9		B	C		
Al	0.30	9		B	C	D	
Fe	0.35	9			C	D	
Sa	0.39	9			C	D	
Pf	0.44	9				D	
Ma	0.68	9					E

Letras distintas indican diferencias significativas(p<=0.05)

4.9. Analysis of variance for pH

Variable	N	R^2	R^2Aj	CV
pH	30	1.00	1.00	0.31

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	0.84	9	0.09	758.13	<0.0001
Variety	0.84	9	0.09	758.13	<0.0001
Error	0.00	20	0.00		
Total	0.84	29			

Test: Tukey Alfa: 0.05 DMS: 0.03211

Error: 0.0001 gl: 20

Variety	Medias	n							
CJ	3.23	3	A						
Fe	3.36	3		B					
CR	3.38	3		B	C				
JP	3.41	3			C				
Al	3.53	3				D			
Ma	3.62	3					E		
Sa	3.66	3						F	
Pf	3.70	3							G
Sm	3.72	3							G
Cu	3.73	3							G

Letras distintas indican diferencias significativas(p<=0.05)

4.10. Analysis of variance for size

Variable	N	R^2	R^2Aj	CV
Diameter	300	0.48	0.46	5.42

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	6.14	9	0.68	29.18	<0.0001
Variety	6.14	9	0.68	29.18	<0.0001
Error	6.78	290	0.02		
Total	12.93	299			

Test: Tukey Alfa: 0.05 DMS: 0.12810

Error: 0.0234 gl: 290

Variety	Medias	n				
CR	2.54	30	A			
CJ	2.70	30		B		
Cu	2.71	30		B		
Fe	2.72	30		B		
Pf	2.86	30			C	
Sa	2.86	30			C	
Sm	2.88	30			C	
JP	2.93	30			C	D
Ma	2.96	30			C	D
Al	3.05	30				D

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2Aj	CV
length	300	0.62	0.60	6.94

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	29.66	9	3.30	51.49	<0.0001
Variety	29.66	9	3.30	51.49	<0.0001
Error	18.56	290	0.06		
Total	48.23	299			

Test: Tukey Alfa: 0.05 DMS: 0.21194

Error: 0.0640 gl: 290

Variety	Medias	n					
Cu	3.05	30	A				
CR	3.21	30	A				
Fe	3.47	30		B			
Sm	3.54	30		B			
CJ	3.61	30		B	C		
Al	3.76	30			C	D	
Ma	3.87	30				D	E
Pf	3.94	30				D	E
JP	3.98	30					E
Sa	4.03	30					E

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2Aj	CV
Volume (cm3)	300	0.53	0.51	20.44

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	0.00	9	0.00	35.63	<0.0001
Variety	0.00	9	0.00	35.63	<0.0001
Error	0.00	290	0.00		
Total	0.01	299			

Test: Tukey Alfa: 0.05 DMS: 0.00307

Error: 0.0000 gl: 290

Variety	Medias	n				
Cu	0.01	30	A			
CR	0.01	30	A			
Fe	0.02	30		B		
CJ	0.02	30		B	C	
Sm	0.02	30		B	C	D
Al	0.02	30			C	D
Pf	0.02	30				D
Sa	0.02	30				D
Ma	0.02	30				D
JP	0.02	30				D

Letras distintas indican diferencias significativas(p<=0.05)

Variable	N	R^2	R^2Aj	CV
Spherical Relation	300	0.44	0.43	7.12

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1.96	9	0.22	25.68	<0.0001
Variety	1.96	9	0.22	25.68	<0.0001
Error	2.46	290	0.01		
Total	4.42	299			

Test: Tukey Alfa: 0.05 DMS: 0.07716

Error: 0.0085 gl: 290

Variety	Medias	n						
Cu	1.12	30	A					
Sm	1.23	30		B				
Al	1.23	30		B				
CR	1.26	30		B	C			
Fe	1.28	30		B	C	D		
Ma	1.31	30			C	D	E	
CJ	1.35	30				D	E	F
JP	1.36	30				D	E	F
Pf	1.38	30					E	F
Sa	1.41	30						F

Letras distintas indican diferencias significativas(p<=0.05)

4.10. Analysis of variance for Total soluble solids

Variable	N	R^2	R^2 Aj	CV
°Brix	30	0.95	0.93	2.25

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	86.74	9	9.64	46.37	<0.0001
Variety	86.74	9	9.64	46.37	<0.0001
Error	4.16	20	0.21		
Total	90.90	29			

Test: Tukey Alfa: 0.05 DMS: 1.31818

Error: 0.2078 gl: 20

Variety	Medias	n					
CR	17.16	3	A				
Al	17.21	3	A				
Cu	19.60	3		B			
Sa	20.00	3		B	C		
Fe	20.47	3		B	C	D	
JP	21.20	3			C	D	E
CJ	21.48	3				D	E
Sm	21.60	3				D	E
Pf	21.62	3				D	E
Ma	22.12	3					E

Letras distintas indican diferencias significativas(p<=0.05)

4.11. Analysis of variance for Titratable acidity

Variable	N	R^2	R^2 Aj	CV
Acidity	30	0.99	0.99	2.61

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	1.58	9	0.18	285.35	<0.0001
Variety	1.58	9	0.18	285.35	<0.0001
Error	0.01	20	0.00		
Total	1.60	29			

Test: Tukey Alfa: 0.05 DMS: 0.07180

Error: 0.0006 gl: 20

Variety	Medias	n					
Sm	0.59	3	A				
Ma	0.63	3	A				
Sa	0.79	3		B			
Pf	0.81	3		B			
Fe	0.95	3			C		
Cu	0.95	3			C		
CJ	1.11	3				D	
Al	1.21	3					E
JP	1.24	3					E
CR	1.24	3					E

Letras distintas indican diferencias significativas(p<=0.05)

4.12. Analysis of variance for Maturity Index

Variable	N	R^2	R^2Aj	CV
Maturity Index	30	0.99	0.98	3.65

Table Analysis of Variance (SC Tipo III)

F.V.	SC	gl	CM	F	Valor p
Modelo	694.48	9	77.16	202.24	<0.0001
Variety	694.48	9	77.16	202.24	<0.0001
Error	7.63	20	0.38		
Total	702.11	29			

Test: Tukey Alfa: 0.05 DMS: 1.78599

Error: 0.3815 gl: 20

Variety	Medias	n							
CR	9.15	3	A						
JP	11.36	3		B					
Al	12.52	3		B					
Fe	14.48	3			C				
Sa	16.51	3				D			
Cu	18.03	3				D	E		
CJ	19.67	3					E	F	
Pf	20.04	3						F	
Ma	23.15	3							G
Sm	24.48	3							G

Letras distintas indican diferencias significativas(p<=0.05)

Appendix 5. Conversion tables (RI to °Brix)

n 20°	Grado Brix	n 20°	Grado Brix	n 20°	Grado Brix	n 20°	Grado Brix
1,3330	0,009	1,3370	2,779	1,3410	5,494	1,3450	8,155
1,3331	0,078	1,3371	2,848	1,3411	5,562	1,3451	8,221
1,3332	0,149	1,3372	2,917	1,3412	5,629	1,3452	8,287
1,3333	0,218	1,3373	2,985	1,3413	5,696	1,3453	8,352
1,3334	0,288	1,3374	3,053	1,3414	5,763	1,3454	8,418
1,3335	0,358	1,3375	3,122	1,3415	5,830	1,3455	8,484
1,3336	0,428	1,3376	3,190	1,3416	5,897	1,3456	8,550
1,3337	0,498	1,3377	3,259	1,3417	5,964	1,3457	8,615
1,3338	0,567	1,3378	3,327	1,3418	6,031	1,3458	8,681
1,3339	0,637	1,3379	3,395	1,3419	6,098	1,3459	8,746
1,3340	0,707	1,3380	3,463	1,3420	6,165	1,3460	8,812
1,3341	0,776	1,3381	3,532	1,3421	6,231	1,3461	8,878
1,3342	0,846	1,3382	3,600	1,3422	6,298	1,3462	8,943
1,3343	0,915	1,3383	3,668	1,3423	6,365	1,3463	9,008
1,3344	0,985	1,3384	3,736	1,3424	6,432	1,3464	9,074
1,3345	1,054	1,3385	3,804	1,3425	6,498	1,3465	9,139
1,3346	1,124	1,3386	3,872	1,3426	6,565	1,3466	9,205
1,3347	1,193	1,3387	3,940	1,3427	6,632	1,3467	9,270
1,3348	1,263	1,3388	4,008	1,3428	6,698	1,3468	9,335
1,3349	1,332	1,3389	4,076	1,3429	6,765	1,3469	9,400
1,3350	1,401	1,3390	4,144	1,3430	6,831	1,3470	9,466
1,3351	1,470	1,3391	4,212	1,3431	6,898	1,3471	9,531
1,3352	1,540	1,3392	4,279	1,3432	6,964	1,3472	9,596
1,3353	1,609	1,3393	4,347	1,3433	7,031	1,3473	9,661
1,3354	1,678	1,3394	4,415	1,3434	7,097	1,3474	0,726
1,3355	1,747	1,3395	4,483	1,3435	7,164	1,3475	9,791
1,3356	1,816	1,3396	4,550	1,3436	7,230	1,3476	9,856
1,3357	1,885	1,3397	4,618	1,3437	7,296	1,3477	9,921
1,3358	1,954	1,3398	4,686	1,3438	7,362	1,3478	9,986
1,3359	2,023	1,3399	4,753	1,3439	7,429	1,3479	10,051
1,3360	2,092	1,3400	4,821	1,3440	7,495	1,3480	10,116
1,3361	2,161	1,3401	4,888	1,3441	7,561	1,3481	10,181
1,3362	2,230	1,3402	4,956	1,3442	7,627	1,3482	10,246
1,3363	2,299	1,3403	5,023	1,3443	7,693	1,3483	10,311
1,3364	2,367	1,3404	5,091	1,3444	7,759	1,3484	10,375
1,3365	2,436	1,3405	5,158	1,3445	7,825	1,3485	10,440
1,3366	2,505	1,3406	5,225	1,3446	7,891	1,3486	10,505
1,3367	2,574	1,3407	5,293	1,3447	7,957	1,3487	10,570
1,3368	2,642	1,3408	5,360	1,3448	8,023	1,3488	10,634
1,3369	2,711	1,3409	4,427	1,3449	8,089	1,3489	10,699

Tabla 1 (Continuación)

n 20°	Grado Brix	n 20°	Grado Brix	n 20°	Grado Brix	n 20°	Grado Brix
1,3490	10,763	1,3530	13,321	1,3570	15,829	1,3610	18,290
1,3491	10,828	1,3531	13,384	1,3571	15,891	1,3611	18,351
1,3492	10,892	1,3532	13,448	1,3572	15,953	1,3612	18,412
1,3493	10,957	1,3533	13,511	1,3573	16,016	1,3613	18,473
1,3494	11,021	1,3534	13,574	1,3574	16,078	1,3614	18,534
1,3495	11,086	1,3535	13,637	1,3575	16,140	1,3615	18,595
1,3496	11,150	1,3536	13,700	1,3576	16,201	1,3616	18,655
1,3497	11,215	1,3537	13,763	1,3577	16,263	1,3617	18,716
1,3498	11,279	1,3538	13,826	1,3578	16,325	1,3618	18,777
1,3499	11,343	1,3539	13,890	1,3579	16,387	1,3619	18,837
1,3500	11,407	1,3540	13,953	1,3580	16,449	1,3620	18,898
1,3501	11,472	1,3541	14,016	1,3581	16,511	1,3621	18,959
1,3502	11,536	1,3542	14,079	1,3582	16,573	1,3622	19,019
1,3503	11,600	1,3543	14,141	1,3583	16,634	1,3623	19,080
1,3504	11,664	1,3544	14,204	1,3584	16,696	1,3624	19,141
1,3505	11,728	1,3545	14,267	1,3585	16,758	1,3625	19,201
1,3506	11,792	1,3546	14,330	1,3586	16,819	1,3626	19,262
1,3507	11,856	1,3547	14,393	1,3587	16,881	1,3627	19,322
1,3508	11,920	1,3548	14,456	1,3588	16,943	1,3628	19,382
1,3509	11,984	1,3549	14,518	1,3589	17,004	1,3629	19,443
1,3510	12,048	1,3550	14,581	1,3590	17,066	1,3630	19,503
1,3511	12,112	1,3551	14,644	1,3591	17,127	1,3631	19,564
1,3512	12,176	1,3552	14,707	1,3592	17,189	1,3632	19,624
1,3513	12,240	1,3553	14,759	1,3593	17,250	1,3633	19,684
1,3514	12,304	1,3554	14,832	1,3594	17,311	1,3634	19,745
1,3515	12,368	1,3555	14,894	1,3595	17,373	1,3635	19,805
1,3516	12,431	1,3556	14,957	1,3596	17,434	1,3636	19,865
1,3517	12,495	1,3557	15,019	1,3597	17,496	1,3637	19,925
1,3518	12,559	1,3558	15,082	1,3598	17,557	1,3638	19,985
1,3519	12,623	1,3559	15,144	1,3599	17,618	1,3639	20,045
1,3520	12,686	1,3560	15,207	1,3600	17,679	1,3640	20,106
1,3521	12,750	1,2561	15,269	1,3601	17,741	1,3641	20,166
1,3522	12,813	1,3562	15,332	1,3602	17,802	1,3642	20,226
1,3523	12,877	1,3563	15,394	1,3603	17,863	1,3643	20,286
1,3524	12,940	1,3564	15,456	1,3604	17,924	1,3644	20,346
1,3525	13,004	1,3565	15,518	1,3605	17,985	1,3645	20,406
1,3526	13,067	1,3566	15,581	1,3606	18,046	1,3646	20,466
1,3527	13,131	1,3567	15,643	1,3607	18,107	1,3647	20,525
1,3528	13,194	1,3568	15,705	1,3608	18,168	1,3648	20,585
1,3529	13,258	1,3569	15,767	1,3609	18,229	1,3649	20,645

n 20°	Grado Brix	n 20°	Grado Brix	n 20°	Grado Brix	n 20°	Grado Brix
1,3650	20,705	1,3690	23,075	1,3730	25,403	1,3770	27,688
1,3651	20,765	1,3691	23,134	1,3731	25,460	1,3771	27,745
1,3652	20,825	1,3692	23,193	1,3732	25,518	1,3772	27,802
1,3653	20,884	1,3693	23,251	1,3733	25,576	1,3773	27,858
1,3654	20,944	1,3694	23,310	1,3734	25,633	1,3774	27,915
1,3655	21,004	1,3695	23,369	1,3735	25,691	1,3775	27,971
1,3656	21,063	1,3696	23,427	1,3736	25,748	1,3776	28,028
1,3657	21,123	1,3697	23,486	1,3737	25,806	1,3777	28,084
1,3658	21,183	1,3698	23,544	1,3738	25,863	1,3778	28,141
1,3659	21,242	1,3699	23,603	1,3739	25,921	1,3779	28,197
1,3660	21,302	1,3700	23,661	1,3740	25,978	1,3780	28,253
1,3661	21,361	1,3701	23,720	1,3741	26,035	1,3781	28,310
1,3662	21,421	1,3702	23,778	1,3742	26,093	1,3782	28,366
1,3663	21,480	1,3703	23,836	1,3743	26,150	1,3783	28,422
1,3664	21,540	1,3704	23,895	1,3744	26,207	1,3784	28,479
1,3665	21,599	1,3705	23,953	1,3745	26,265	1,3785	28,535
1,3666	21,658	1,3706	24,011	1,3746	26,322	1,3786	28,591
1,3667	21,718	1,3707	24,070	1,3747	26,379	1,3787	28,648
1,3668	21,777	1,3708	24,128	1,3748	26,436	1,3788	28,704
1,3669	21,836	1,3709	24,186	1,3749	26,493	1,3789	28,760
1,3670	21,896	1,3710	24,244	1,3750	26,551	1,3790	28,816
1,3671	21,955	1,3711	24,302	1,3751	26,608	1,3791	28,872
1,3672	22,014	1,3712	24,361	1,3752	26,665	1,3792	28,928
1,3673	22,073	1,3713	24,419	1,3753	26,722	1,3793	28,984
1,3674	22,132	1,3714	24,477	1,3754	26,779	1,3794	29,040
1,3675	22,192	1,3715	24,535	1,3755	26,836	1,3795	29,096
1,3676	22,251	1,3716	24,593	1,3756	26,893	1,3796	29,152
1,3677	22,310	1,3717	24,651	1,3757	26,950	1,3797	29,208
1,3678	22,369	1,3718	24,709	1,3758	27,007	1,3798	29,264
1,3679	22,428	1,3719	24,767	1,3759	27,064	1,3799	29,320
1,3680	22,487	1,3720	24,825	1,3760	27,121	1,3800	29,376
1,3681	22,546	1,3721	24,883	1,3761	27,178	1,3801	29,432
1,3682	22,605	1,3722	24,941	1,3762	27,234	1,3802	29,488
1,3683	22,664	1,3723	24,998	1,3763	27,291	1,3803	29,544
1,3684	22,723	1,3724	25,056	1,3764	27,348	1,3804	29,600
1,3685	22,781	1,3725	25,114	1,3765	27,405	1,3805	29,655
1,3686	22,840	1,3726	25,172	1,3766	27,462	1,3806	29,711
1,3687	22,899	1,3727	25,230	1,3767	27,518	1,3807	29,767
1,3688	22,958	1,3728	25,287	1,3768	27,575	1,3808	29,823
1,3689	23,017	1,3729	25,345	1,3769	27,632	1,3809	29,878

Tempe-ratura °C	Grado Brix										
	0	5	10	15	20	25	30	40	50	60	70
Sumar											
21	0,06	0,07	0,07	0,07	0,07	0,08	0,08	0,08	0,08	0,08	0,08
22	0,13	0,13	0,14	0,14	0,15	0,15	0,15	0,15	0,16	0,16	0,16
23	0,19	0,20	0,21	0,22	0,22	0,23	0,23	0,23	0,24	0,24	0,24
24	0,26	0,27	0,28	0,29	0,30	0,30	0,31	0,31	0,31	0,32	0,32
25	0,33	0,35	0,36	0,37	0,38	0,38	0,39	0,40	0,40	0,40	0,40
26	0,40	0,42	0,43	0,44	0,45	0,46	0,47	0,48	0,48	0,48	0,48
27	0,48	0,50	0,52	0,53	0,54	0,55	0,55	0,56	0,56	0,56	0,56
28	0,56	0,57	0,60	0,61	0,62	0,63	0,63	0,64	0,64	0,64	0,64
29	0,64	0,66	0,68	0,69	0,71	0,72	0,72	0,73	0,73	0,73	0,73
30	0,72	0,74	0,77	0,78	0,79	0,80	0,80	0,81	0,81	0,81	0,81