THE COMPOSITION AND PROCESSING OF GUAVA

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SUMMARY

The guava fruit is an excellent source of ascorbic acid and also lends itself to relatively simple processing techniques. A wide range of products such as beverages, dehydrated products, jelly and slices in syrup can all be prepared from guava. Even the seeds could be utilised in animal feeds.

This paper reviews the composition and processing of guava - a much neglected crop in the Caribbean.

1. INTRODUCTION

Guava (Psidium guajava L.) is a tropical fruit native to Central and South America. It has been introduced to several other tropical and semitropical regions including Hawaii, India and the African continent. Well liked principally because of its strong and characteristic flavour, some varieties of guava have been reported to contain very high quantities of ascorbic acid. These factors together with the fact that the guava fruit is well suited to processing have earned the guava such names as "Apple of the Tropics" and "Poorman's Apple".

Broadly classifying guava, two distinct varieties are recognized based on the flesh colour. The first varies from white to yellow and the other from pink to red. In the Western World, the pink-fleshed varieties are generally preferred whereas in India, the white-fleshed varieties are more popular.

2. COMPOSITION

2.1 Physical Characteristics

The guava fruit is composed of a firm fleshy portion which has on its outside a very thin skin, and on the inside a seed-core in which the seeds are held together by a thick pulpy material. The mean physical characteristics of three important Indian varieties of guava are summarized in Table 1.

TABLE 1

PHYSICAL CHARACTERISTICS OF THREE VARIETIES OF INDIAN GUAVAS (SEHGAL AND SINGH, 1965)

CHARACTERISTICS	VARIETY		
	SAFEDA	LUCKNOW 49	RED-FLESHED
SHAPE	SUB-GLOBOSE TO BROADLY OBOVOID GLO-BOSE	SUB-GLOBOSE	OBOVATE GLO-BOSE TO SUB-GLOBOSE
Height cm	6.93	8.15	6.78
Diameter cm	6.97	8.36	6.63
Weight g	161.31	260.36	144.33
Flesh Thickness cm	1.32	1.62	1.15
Flesh Colour	cream white	cream white	pink
Flesh Texture	smooth	smooth	coarse
Seed Cavity (dia) cm	4.66	5.14	4.3
Seed Weight g	3.23	6.31	2.5

Although the shape of the guavas in Table 1 are all globose, some varieties are pear shaped such as the South American variety Eloina. Others are small such as the variety Periforme de Trujillo which weighs between 60 g to 90 g[13] and a wild Puerto Rican variety which averages 36.2 g[56].

The inedible portion of the guava, the seeds, make up on the average about 4 percent of the fruit. There is one seedless variety which, unfortunately, is a very shy bearer. This seedless fruit has a small cavity at its centre and weighs on the average 71.8 g[77].

2.2 Chemical Composition

The average composition of three important varieties of Indian guavas obtained by analysing the peeled fruits at the yellowing stage of maturity are summarized in Table 2.

TABLE 2

COMPOSITION OF THREE INDIAN VARIETIES OF GUAVA (TEAOTIA ET AL., 1962)

CONSTITUENTS	VARIETY		
	SAFEDA ALLAHABAD	LUCKNOW 49	RED-FLESHED
Total soluble solids ^{o}B	12.6	11.6	15.6
pH	3.2	3.3	3.4
Acidity (as citric acid) %	0.240	0.503	0.280
Ascorbic Acid mg/100 g	187.941	168.665	106.018
Sugars (reducing) %	6.09	2.385	3.781
Sugars (non-reducing) %	1.780	5.302	2.462
Tannin %	0.370	0.168	0.134
Starch %	0.647	0.660	0.607
Pectic substances (soluble) %	0.024	0.676	1.193
Pectic substances (total) %	0.304	1.261	1.624
Crude Fibre %	3.132	3.248	4.584

The physico-chemical changes occurring in the guava fruit from the time of fruit set to maturity, ripening and senescence have been studied for several varieties of guava[55,63,71,72]. The trend of the chemical changes are summarized below:

(i) Throughout the life of the fruit, there is a steady increase in the total soluble solids and in the sugar content. There is more of reducing sugars at all stages. Moisture content also increases continually.

(ii) Both ascorbic acid and total pectins follow a similar trend, they continue increasing with the maximum concentration being reached in the fully ripe stage, after which they start decreasing.

(iii) Titratable acidity increases up to the beginning of the ripening stage after which it falls off. On the other hand pH is at its lowest level in the final stages of ripening.

(iv) At about the mid-point between fruit set and maturation both concentration of starch and that of tannins are at their maxima. After these peaks are reached both then decrease steadily to their minima in the over ripe fruit.

(v) Crude fibre content of the developing fruit follows a continuous downward trend.

2.3 Vitamins and Minerals

Over the past several years, the guava has come under increased scrutiny because apart from its strong flavour, certain varieties have been found to contain very high amounts of ascorbic acid. Ranking second only to the West Indian cherry, the Indian varieties "Lucknow 49" and "White Supreme" have been found to contain as much as 364.5 mg/100 g and 319.0 mg/100 g of ascorbic acid, respectively[75]. A Hawaiian variety, Lupi-1 has been found to contain 492.0 mg/100 g of ascorbic acid[34]. High concentrations of ascorbic acid have been reported by several other workers[42,43,80,57,13]. Values as low as 20 mg/100 g have been found in other varieties[56].

The concentration of ascorbic acid is not uniform throughout the fruit, the skin has the highest concentration and it decreases gradually inwards[80,28].

There seems to be no apparent relation between flesh colour and ascorbic acid content, the two Indian varieties mentioned earlier are white-fleshed whereas Lupi-1 is pink-fleshed. Also, wild guavas have been reported to have less ascorbic acid than cultivated ones[9,42,43].

The guava fruit is also recognized as a source of vitamins other than ascorbic acid[22,43,81]. Values for these nutrients as well as some minerals are summarized in Table 3.

TABLE 3

MINERAL AND VITAMIN CONTENTS OF GUAVA

NUTRIENT	RANGE mg/100 g
Calcium	13-14
Phosphorous	22.5-36.9
Iron	0.82-5
Carotene	0.013-0.028
Thiamine	0.036-0.08
Riboflavin	0.032-0.08
Niacin	0.80 -2.32

2.4 Organic Acids

Total acidity as citric acid has been found to vary considerably from variety to variety. Whereas the acidity of those varieties shown in Table 2 are all less than 1.0 percent, two South American varieties have been reported to have total acidities exceeding 1.0%. The varieties Periforme de Trujillo and Dominica Roja were found to contain 1.672% and 1.426% total acidity, respectively[13].

In three varieties of guava studied by Santini[59], citric acid was the chief acid found, with tartaric, malic and ascorbic acids in lesser quantities. During the growth and maturity of both white and red-fleshed varieties, tartaric, citric,malic, succinic and ascorbic acids were among these detected by Agnihotri et al[1]. Tartaric acid was, however, reported to be absent from the major non-volatile acids of guava, as described by Chan et al[9]. These authors found malic and citric acids in almost equal quantities in cultivated guavas. In wild guavas,citric acid was predominant. The other important organic acids identified by them were lactic, galacturonic and ascorbic acid. Cultivated guavas were also found to contain less lactic acid than wild ones.

2.5 Sugars

As ripening of the fruit progresses, the sugar content of the guava increases. The major free sugars identified are sucrose, glucose and fructose[10,63,68]. Small quantities of arabinose; rhamnose, xylose, ribose, glactose and an unidentified oligo-saccharide have been detected by Katayama[29] using thin layer chromatography.

The total and reducing sugar contents of different varieties of guava have been studied by several workers[15,42,43,73]. Though reducing sugars are generally more abundant than non-reducing sugars, some white-fleshed varieties show a greater non-reducing sugar content[75]. Fructose is the major reducing sugar[10,63].

2.6 Flavour Components

Pleasant, aromatic, acidic, fine and apricot have been used to describe the flavours of Indian varieties of guava[75]. Of the white-fleshed varieties, seven were classified as pleasant, five aromatic and one fine. Of the red-fleshed varieties, two were pleasant, two acidic and one apricot. Guava odour constituents which have been found to be heat stable were first associated with carbonyl compounds[46].

From the volatile constituents of guava puree, a total of 22 compounds were later identified[73]. Of these, cis-3-hexen-1-ol, hexanol and hexanal were predominant. A large number of aromatic compounds were predominant. A large number of aromatic compounds were also found, the main ones being methylbenzoate, β-phenethyl acetate and methyl cinnamate. Also present were some terpenes, terpene alcohols and sesquiterpenes including caryophylene. Over 100 components have been separated from oil extracted from guava puree[78].

2.7 Pectin

Guava has always been reported as a very good source of pectin. It has been considered one of the easiest fruits from which to make jam or jelly. Guava pectins produce good gels with 65% soluble solids, stable at pH 2.1 to 2.4[16]. The pectin concentration is highest in the skin of the fruit.

Studies in the changes in the quality and recovery of pectin, during refrigerated and ordinary storage from green and ripe guavas, showed that total pectins decreased more rapidly in the ripe fruits. Also, changes in the methoxyl and anhydrouronic acid of the pectin were similar. In refrigerated storage, however, the methoxyl fraction of ripe guavas underwent a slower breakdown than the green ones[48]. Hydrolysed pectin obtained from Indian guavas was found to contain D-galacturonic acid, D-galactose and L-arabinose, whereas there was no glucose sugar[48].

2.8 Stone Cells

The stone cells of the guava which are found in the fleshy portion of the fruit are responsible for the gritty or granular texture of the guava. Generally, the white-fleshed varieties of guava have less stone cells than the red-fleshed varieties. These cells are predominantly lignineous and cellulosic in nature[62]. Approximately, they consist of ash 0.66, protein 3.54, lignin 37.42, fat 0.35, cellulose 59.45%. The crude fibre content was determined as 56.60%.

2.9 Guava Seeds

The composition of guava seeds obtained for two varieties of Indian guavas is presented in Table 4.

TABLE 4

COMPOSITION OF GUAVA SEED POWDER (KRISHNA ET AL 1969)

CONSTITUENT	VARIETY	
	LOCAL RED-FLESHED	ALLAHABAD WHITE-FLESHED
Moisture %	5.38	5.80
Ash %	1.66	1.26
Crude Fat %	10.11	15.10
Crude Protein %	7.05	10.77
Starch %	8.71	10.63
Crude Fibre %	58.41	48.63
Pectin (Ca-pectate) %	0.61	1.12
Carbohydrates (other than starch) %	8.09	6.92
Calcium mg/100 g	124.24	194.40
Phosphorous mg/100 g	116.30	184.90
Iron mg/100 g	2.44	3.44

3. PROCESSING

The guava fruit is easily processed into many products such as jams, jellies, candies and as fruit in syrup. Various types of beverages, dehydrated products, guava cheese, and wine can also be prepared from the fruit. Within recent times guava is being used as a flavouring in ice-cream, yogurt and soured milk products.

Although the guava tree is a prolific bearer even on marginal lands, a lot of the fruit goes to waste. One of the major reasons for this is the fact that the guava season is very short resulting in a glut on the market. Some type of primary processing of such highly seasonal fruits is needed to stabilize a processing industry dealing with this type of produce. For this reason, preparation and preservation of guava pulp which can be lated used to make other food products has been studied by several workers[8,14,18,20,26,30,36,58,60].

3.1 Guava Pulp

Processing of the fruit so as to obtain a smooth pulp or puree or paste as it is also called, can be obtained by both 'hot' and 'cold' methods. In 'cold' processing, the washed fruits are first shredded and then passed through a fruit pulper[8,20,58]. In the 'hot' process, the fruits are steamed after shredding or as a whole to soften them or simply steamed as in a blanching process prior to pulping[20,26,44]. To minimise wastage and to facilitate pulping, macerating the fruit with an equal quantity of water before pulp extraction has also been employed. Cooking of the macerated fruit with its own weight of water to soften the pulp has also been suggested[26].

For maximum pulp recovery when no water is added the pulping process should be carried out in three distinct stages according to Luh[34]. The stages are:

i) Shredding of the fruit, this is essential as the guava fruit, even in the fully ripe fruit is very firm.

ii) Separation of the seeds. A paddle type fruit pulper with a screen of 0.8 to 1.2 mm is considered most suitable. A screw type pulper can also be successfully employed[41]. To minimize wastage, recycling of the seed portion from the pulper is often necessary.

iii) Finishing. This step is essential for a good quality product. A machine similar to the paddle type pulper, but with rubber lined paddles and with a screen with 0.5 mm holes is recommended for the removal of the stone cells. Another type of paddle which consists of a system of brushes rubbing against the screen may also be used. The stone cells if not removed, make the pulp very gritty and also dilute the colour of the pink-fleshed varieties of guava pulp.

A stone or mustard mill can also be successfully used to eliminate the gritty texture through a process of size reduction. As expected, the colour is affected but yields of pulp are increased. Vitamin C losses are also greater in this method[59].

Hot extraction yields a pulp which is more viscous than cold extracted pulp most probably due to the destruction of the pectic enzymes. A similar behaviour is noted with tomatoes[37]. However, Vitamin C destruction is greater during hot pulping[20].

Guava pulp has been preserved by freezing, chemical preservatives and by canning. Freezing of heated and unheated pulp was first investigated by Orr et al[45]. They found that both pulps stored at $-18^{o}C$ kept well for 52 weeks. The keeping quality was further enhanced by the addition of sugar. Excellent storage behaviour of guava pulp by freezing at $-18^{o}C$ to $-20^{o}C$ has also been reported by other workers[18,30,36]. The Vitamin C content of frozen pulp remains relatively unchanged during storage.

Of the various chemical preservatives tested, a minimum of 700 ppm of sulphur dioxide has been found to be best for both pasteurized and unpasteurized pulp. The keeping quality of the pasteurized pulp, heated to at least $85^{o}C$, is far superior to the unpasteurized one[20,36].

When pasteurized at $94^{o}C$ and preserved with 2000 ppm sodium metabisulphite, ascorbic acid was found to be stable for 6 months, whereas for both pasteurized only and unpasteurized with 2000 ppm sodium metabisulphite, the ascorbic acid fell off rapidly in three months[36]. Removal of sulphur dioxide from stored pulps prior to further use can be successfully achieved by 0.25% hydrogen peroxide. No flavour change has been reported to occur by this method[14].

The use of sodium benzoate as a preservative for guava pulp is not advised as it causes a brown discolouration[20].

Canning of guava pulp results in high retention of Vitamin C, superior to the use of 700 ppm sulphur dioxide[20]. Asceptic canning, heating for 30 sec at $115^{o}C$ has been found to be superior to hot fill canning[30].

Sulphur dioxide, potassium sorbate and sodium benzoate have been studied for preserving guava pulp obtained from a mixture of shredded fruit and an equal quantity of water by both hot and cold methods[26]. Ascorbic acid was better preserved in the cold extracted pulp but gelation and separation of a clean liquid in the samples preserved by these chemicals appeared after 26 weeks. Sodium benzoate and potassium sorbate resulted in browning and loss of flavour and ascorbic acid. 700 ppm of sulphur dioxide was reported as best.

In a study on the non-enzymatic browning of guava pulps preserved by sulphur dioxide and sodium benzoate, browning was found to be least in heated pulp with all air removed and with 700 ppm sulphur dioxide[6]. Deaeration is therefore an important step in obtaining a high quality product.

3.2 Jelly

The traditional method of preserving guavas is in the form of a jelly. For good results, ripe fruit is cut into slices and covered with an equal weight of water containing 2.5 g to each kilogram of fruit. The contents after heating for 30 minutes are strained through a thick cloth. The liquid portion is allowed to settle overnight. The clear supernatant is boiled with its own weight of sugar and the final acidity adjusted to 0.6%. The end point is reached when the boiling point of the mass is 106°C.

Jelly and jam of good quality can also be prepared from pulp preserved by canning and with sulphur dioxide[20].

In guava jelly stored at 37°C, the ascorbic acid was almost totally destroyed after 57 weeks in both natural and fortified jellies[7]. Sulphur dioxide is said to have a preserving effect on the ascorbic acid in jellies.

3.3 Slices in Syrup

Canning of guava halves in syrup has been extensively studied[35,52,54,66,75]. In this method of preservation, the fruits are first peeled and then cored. Lye peeling employing a boiling solution of sodium hydroxide (2.5%) is normally used and the seed core is scooped out by hand. Of 13 white-fleshed and 5 red-fleshed Indian varieties of guavas which were compared for suitability of canning, the Safeda Allahabad, a white-fleshed variety was found most suitable[75].

For canning, the fully ripe stage of the fruit was found most suitable. Flavour and aroma increased with increasing ripeness but texture showed deterioration.

The white-fleshed guava has been found to develop pink discolouration arising from the presence of leucocyanidin and leucodelphinidin[52]. Sugar syrup containing 0.06% citric acid and 0.05% ascorbic acid, inhibits this pink discolouration[66]. Canning of guavas results in considerable loss of Vitamin C since the fruits are peeled. The skin contains the highest concentration of this vitamin.

3.4 Beverages

Several types of guava beverages have been evaluated to ascertain their stability during storage. Best flavour was obtained from shredded fruit that was first boiled with an equal weight of water and screened to remove the pulpy liquid portion[28]. Typical formulae for guava nectar base and ready-to-serve beverage are:

Nectar base :	Pulp	- 1 kg
	Sugar	- 1 kg
	Citric acid (if none added to pulp)	- 20 g
	(if added to pulp at 5g/kg)	- 15 g
	Potassium metabisulphite	- 1.5 g
Ready-to-serve beverage:	Pulp	- 1 kg
	Sugar	- 1 kg
	Water	- 6 L
	Citric acid as before	

Peeling of the fruit and carbonation were reported to adversely affect the flavour. Nectar base prepared from 100 lb pulp, 54 lb sugar and colouring matter have been successfully preserved by freezing and canning[60].

Guava juice has also been prepared with the help of pectinases[27,44]. This juice contains almost all the nutrients of the edible portion of the fruit. A carbonated beverage prepared from clarified guava pulp and preserved with sulphur dioxide was found to be acceptable over a 72 day storage trial although the ascorbic acid fell from 35.1 to 2.8 mg/100 ml[74].

Sugared (40^{o}B) and single strength (unsugared) guava juice preserved with potassium metabisulphite at levels of 2.8 and 5.6 g/3.93 kg juice and metabisulphite and sodium citrate (10g/3.93kg) were studied during storage for 270 days. The single strength juice retained more ascorbic acid (35%) and sodium citrate aided the retention of colour and flavour of only the sugared juice[65].

Wine prepared from guava has been reported to be very well accepted.[4]

3.5 Dehydrated products

Dehydrated guava pulp has been obtained by vacuum shelf drying, foam mat drying and freeze drying. Addition of an equal quantity of sugar to the pulp before vacuum shelf drying imparted better texture and colour whereas flavour remained unaffected during storage at less than 1.4% moisture and less than 51.3% relative humidity[41].

In-package dessication improved the keeping quality of the dehydrated products.

An important feature of guava pulp in foam mat drying was that the pulp foamed easily without the addition of a stabilizer or foam inducer[5].

The hydroscopicity of vacuum-puff freeze dried guava nectars during storage was found to be influenced by sucrose and calcium salts. The time for caking to appear during storage was largely proportional to sucrose concentration. Lower sucrose concentration also resulted in greater water absorption. 0.1% each of calcium oxide and calcium hydrogen orthophosphate accelerated caking in some cases but caused less moisture absorption[39].

Nutrients remain almost unaffected in both freeze dried and oven dried pulps[17].

A simple method for the preparation of guava powder has been developed by Khurdiya and Roy[31]. Whole guavas are lye peeled, quartered, cored and exposed to sulphur fumes. The sulphured quarters are then dried in a cabinet drier and powdered. Quality of the product is reported to be enhanced by storage in aluminium/polyethylene composite film pouches.

Intermediate moisture guava has been prepared by the immersion equilibration procedure using a soak solution containing glycerol, sucrose, water and potassium sorbate. Canned samples remained acceptable for more than six months at $0^{o}C$ but for less than six months when stored at $25-30^{o}C$. Higher storage temperatures resulted in weakening of flavour beyond 4 months and increased browning. The product remained microbiologically sound[24].

3.6 Storage of Whole Fruit

Refrigerated storage has been found to prolong the life of the fruit up to 4 weeks under optimum conditions. A combination of $8^{o}-10^{o}C$ and a relative humidity of 85-90% were found to be most suitable[69]. For storage at room temperature, a pliofilm wrap was found to be advantageous. Relative changes in some constituents of guava after storage for 6 days under different conditions are given in Table 5.

TABLE 5

CONSTITUENTS AS PERCENTAGE OF ORIGINAL CONCENTRATION IN STORED GUAVAS (SASTRY, 1965)

CONSTITUENT	ROOM TEMPERATURE		COLD STORAGE
	OPEN STORAGE	PLIOFILM WRAP	0-4°C
Protein	90.96	96.70	94.51
Starch	0.00	28.45	79.45
Reducing Sugars	119.00	116.50	114.05
Sucrose	108.10	97.23	233.30
Total Sugars	118.40	115.17	111.82

Coating the fruit with a fungicidal wax emulsion is also beneficial in extending the life of the fruit as well as in preventing spoilage during storage at room temperature[2]. The effect of dipping the fruits for 30-60 seconds in waxol-o-emulsion containing 9.0% solids and 0.5% sodium orthophenyl phenate hexamine are summarized in Table 6. Benlate has also been found to be an effective fungicide[70].

TABLE 6

CHANGES IN COMPOSITION AND MARKETABILITY OF WAXED AND UNWAXED GUAVAS (AGNIHOTRI AND RAM, 1972)

	After 9 days at 20°-25°C and 54-57% Relative Humidity	
	WAXED	UNWAXED
Loss in Weight %	10.00	16.79
Reducing Sugars %	5.20	4.81
Ascorbic Acid mg/100g	160	118
Marketable Fruits %	70	45

An optimum radiation dose of 30 k rad using γ radiation on mature green guavas was found to delay ripening by five days and for longer periods if packaged in polyethylene film or wax paper. Irradiation caused a reduction in ascorbic acid. This reduction disappeared during storage. Total solids and acidity were not affected by irradiation. At the end of the storage test, texture was much better in irradiated fruit. The fruit wrapped in polyethylene were best from the organoleptic evaluation and moisture loss[3].

3.7 Utilization of Waste

In the canning of guavas, wastage is probably highest as the halves constitute about 40-70% of the fruit depending upon the variety. It has been suggested that guava cheese can be prepared from the skin and pulp of the seed core[33]. A recipe developed for making guava cheese is:

Pulp	x kg
Sugar	0.67 xy kg (y = kg of sugar required for 1 kg pulp as for jelly manufacture)
Citric Acid	280 g per 100 kg sugar
Common Salt	875 g per 100 kg sugar
Vegetable fat	1.6 kg per 100 kg sugar

The various ingredients, except the acid, are heated together when the temperature reaches 105°C, the citric acid is then added and the mass boiled until the boiling point reaches 110°C. The cooked mass is then spread in the form of a sheet and allowed to set.

The guava seed powder, Table 4, is said to compare favourably with wheat bran as animal feed. The high crude fibre content is a problem and for this use it may have to be mixed with other feed containing less fibre[32].

4. CONCLUSIONS

The guava tree grows and bears even on poor soils. Yields in excess of 20 tons of fruit per acre are possible on fertile soils. Here we have a crop well adapted to the Caribbean area where it can be found growing in the wild and shown to have a tremendous potential for development. By proper selection and development of varieties for processing, it is possible to turn out a range of food products which are both highly nutritious and flavourful. Also, there is little or no wastage as even the seeds can be utilised in livestock feeds - a scarce commodity in the region.

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