PHYSICO-CHEMICAL CHARACTERIZATION OF SAPOTA (*Achras sapota*) GERMPLASM IN THE SOUTH-WESTERN REGION OF BANGLADESH

A thesis

Submitted to

Biotechnology and Genetic Engineering Discipline, Life Science School

Khulna University

For the partial fulfillment of requirement's for the degree of one and half years

Master of Science in Biotechnology and Genetic Engineering

Submitted by

MD. SHAHJAHAN ALI

Examination Roll No: MS-080708

Session # 2007-08

BIOTECHNOLOGY AND GENETIC ENGINEERING DISCIPLINE

LIFE SCIENCE SCHOOL, KHULNA UNIVERSITY

KHULNA-9208, BANGLADESH

SEPTEMBER, 2011

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LIFE SCIENCE SCHOOL, KHULNA UNIVERSITY

KHULNA-9208, BANGLADESH

SEPTEMBER, 2014

DEDICATED

TO MY

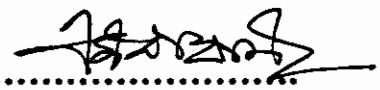
MOST RESPECTABLE PARENTS

TITLE

PHYSICO-CHEMICAL CHARACTERIZATION OF SAPOTA (*Achras sapota*) GERMPLASM IN THE SOUTH-WESTERN REGION OF BANGLADESH

DECLARATION

This thesis report is the original research work of the authors, except as otherwise stated. The material presented has not submitted either in whole or in part for a degree for this or any other university. The findings of the research have not been/will not be published anywhere without the written concurrence of the concerned supervisor. Legal action would be taken in any case of infringement regarding the declaration.



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Acknowledgement

At the very beginning, I offer our deepest gratitude to the Almighty Allah for all His merciful blessings bestowed upon us. Allah, to Whom all praises, goes for enabling us to complete our research work.

The present work was carried out in the Molecular Horticulture Laboratory of Agrotechnology Discipline, Khulna University, Khulna-9208, Bangladesh. Therefore, I am grateful to the authority for providing all the facilities.

Also I am very grateful to our honorable supervisor, **Dr. Md. Abdul Mannan,** Professor, Agrotechnology Discipline, Khulna University, Khulna-9208, Bangladesh for his systematic supervision, indefatigable guidance and enthusiastic support without what I could have nothing.

I am also grateful to co-supervisor, **Professor Md. Raihan Ali,** Biotechnology and Genetic Engineering Discipline for his assistance, encouragement, constant and untiring help and technical suggestion to perform the research work.

I would like to thank to **Sk. Mohibullah,** Research Assistant, Molecular Horticulture laboratory, Agrotechnology Discipline, Khulna University, Khulna-9208, Bangladesh for his overall assistance during the study period.

I would like to thank USDA for financial support for the project entitled ``Evaluation of fruit germplasm available in the South-western Region of Bangladesh.

Finally, I would like to express my deepest and heartfelt gratitude to our father, mother, elder and younger brothers and sisters for their moral encouragement, special support, inspiration and enthusiasm throughout the work.

The author

ABSTRACT

The research work was carried out at Horticulture laboratory, Agrotechnology Discipline, Khulna University, Khulna-9208, Bangladesh to determine the physico-chemical characteristics of 30 selected sapota germplasm available in the south-western region of Bangladesh during February to July, 2011. The experiment was laid out Molecular in Completely Randomized Design (CRD) with three replications. A significant variation was found among the germplasm in relation to fruit characteristics and organoleptic taste. Better performance was showed by germplasm No.80 in respect of individual fruit weight (94.39gm), edible portion (84.89gm) and vitamin-C content (11.80mg/100g). The highest fruit width (5.33cm) was observed in germplasm No. 63, the highest length (5cm) in germplasm No. 51. While germplasm No. 62 the highest pH (6.54) while the highest TSS (26.00%) was recorded the highest in germplasm No.54. Contents of carotenoids 76 (0.41mg /100 g), anthocyanin(1.28 mg /100 g) and flavonoids(15.57 g /100g) were highest in the germplasm 76, 66 and 72 respectively. The overall findings indicate that sapota is rich in nutrients.

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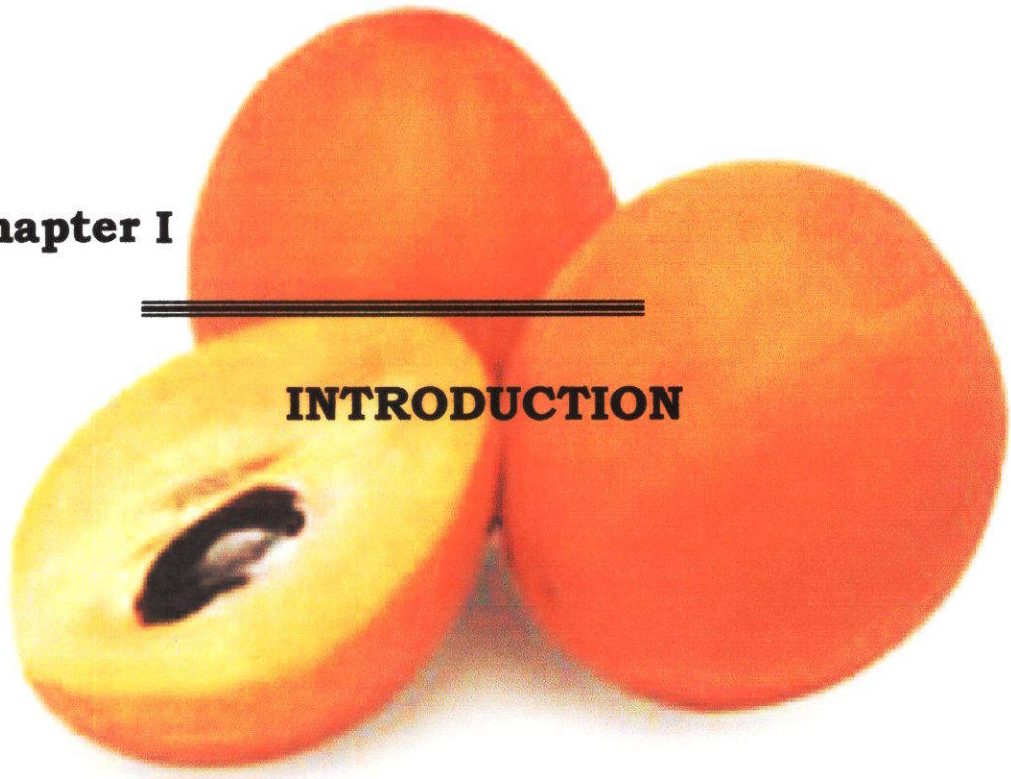
Chapter I



INTRODUCTION

Introduction

Sapota (*Achras sapota*) belongs to the domain: *Eukaryota,* kingdom:*Plantae*,subkingdom: *Viridaeplantae*, phylum: *Tracheophyta* , subphylum: *Euphyllophytina* , infraphylum: *Radiatopses*, class: *Magnoliopsida* , subclass: *Dillenitidae* , superorder: *Primulanae* ,order: *Sapotales* , family: *Sapotaceae* , genus: *Achras* , species: *sapota,* and botanical name: *Achras sapota.*

Sapota, popularly known in India as chiku, is native to tropical America most probably to south Mexico or Central America. This plant is also grown for its Latex. Chicle and gutta parcha are extracted from its latex. These are used as a base material in chewing gum and in some other industrial products. In India it is cultivated for fruits which are liked all over the country. The fruit is a fleshy berry, variable in shape, size and weight (75-150g). The skin is thin, rusty brown somewhat scurfy looking like Irish potato, and the pulp soft, melting, crumbling with a sandy or granular texture with 1-5 hard, black seeds. The fruit is a good source of digestible sugar (12-18%) and an appreciable source of protein, fat, fibre, minerals, calcium and iron. It has become a very popular fruit crop in Gujarat, Maharashtra, Karnataka, Tamilnadu, Andhra Pradesh and Kerala. It has now spread all over the tropical belt and is being grown as a major commercial crop in India, Sri Lanka, Indonesia, Malaysia and Bangladesh. The tree grows very fast and is wind and drought resistant suitable for dry arid regions with scanty rains. However, irrigation during summer season results in good fruit yield. Seeds brown or black, shiny blackish brown, flattened shape and large. Brown seeds contain saponins, quercetin, and oil as much as 23 percent.

In addition to a rich sugar contain other nutrients such as minerals, vitamins, carbohydrates and dietary fiber. The fruit is also good for heart health and blood vessels. Sapodilla fruit (*Achras sapota* L) sweet fragrance and taste delicious. Brown fruit is usually consumed in fresh condition. Taste of the sap is still often attached to the mouth. Under conditions of ripe, this fruit can be made into a beverage or as a mixture of ice cream. However, it has not been commercially cultivated all over the world. In India, Sri Lanka, the Philippines, Mexico, Venezuela, Guatemala, and Central America, sapodilla fruit is cultivated commercially. Sapodilla seeds should not be consumed because hydrocyanic acid content high enough to be toxic. Meanwhile, interest sapodilla is a key

ingredient in parem, namely traditional medicine powder rubbed on the body in new mothers. Sapodilla fruit, sweet flavor makes the fruit's many fans. This fruit is a good source of potassium, i.e 193 mg/100 g. On the other hand, sapodilla also has low sodium content, 12 mg/100 g. Comparison of potassium and sodium content reaches brown 16:1 makes very good for the heart and blood vessels. Apart from potassium rich, brown also contains a number of other important minerals. Vitamin C can react with a variety of minerals in the body. Vitamin C plays an important role in the metabolism of copper. In addition, consumption of adequate amounts of vitamin C can help increase iron absorption. Vitamin C can also interact with a variety of other vitamins such as vitamin E which functions as an antioxidant. Sapodilla fruits also contain folic acid, 14 g. mkg/100 Folic acid is needed for the body's red blood cell formation. Folic acid also helps to prevent the formation of homocysteine which is very harmful for health. Other vitamins also contained in brown fruit are: riboflavin, niacin, B6, and vitamin A. While it can be used as a source of vitamins and minerals. Sapodilla should not be given to infants because of the sap are feared to disturb the digestive tract. Sapodilla fruit also contains a lot of sugar so good for use as an energy source. However, this fruit is not recommended for people with diabetes mellitus because it can increase blood sugar levels quickly.Sapodilla can grow to more than 30 m (98 ft) tall with an average trunk diameter of 1.5 m (4.9 ft). The average height of cultivated specimens, however, is usually between 9 to 15 m (30 to 49 ft) with a trunk diameter not exceeding 50 cm (20 in). It is wind-resistant and the bark is rich in a white, gummy latex called chicle. The ornamental leaves are medium green and glossy. They are alternate, elliptic to ovate, 7–15 cm long, with an entire margin. The white flowers are inconspicuous and bell-like, with a six-lobed corolla. (Mark, *et al., 2010)*

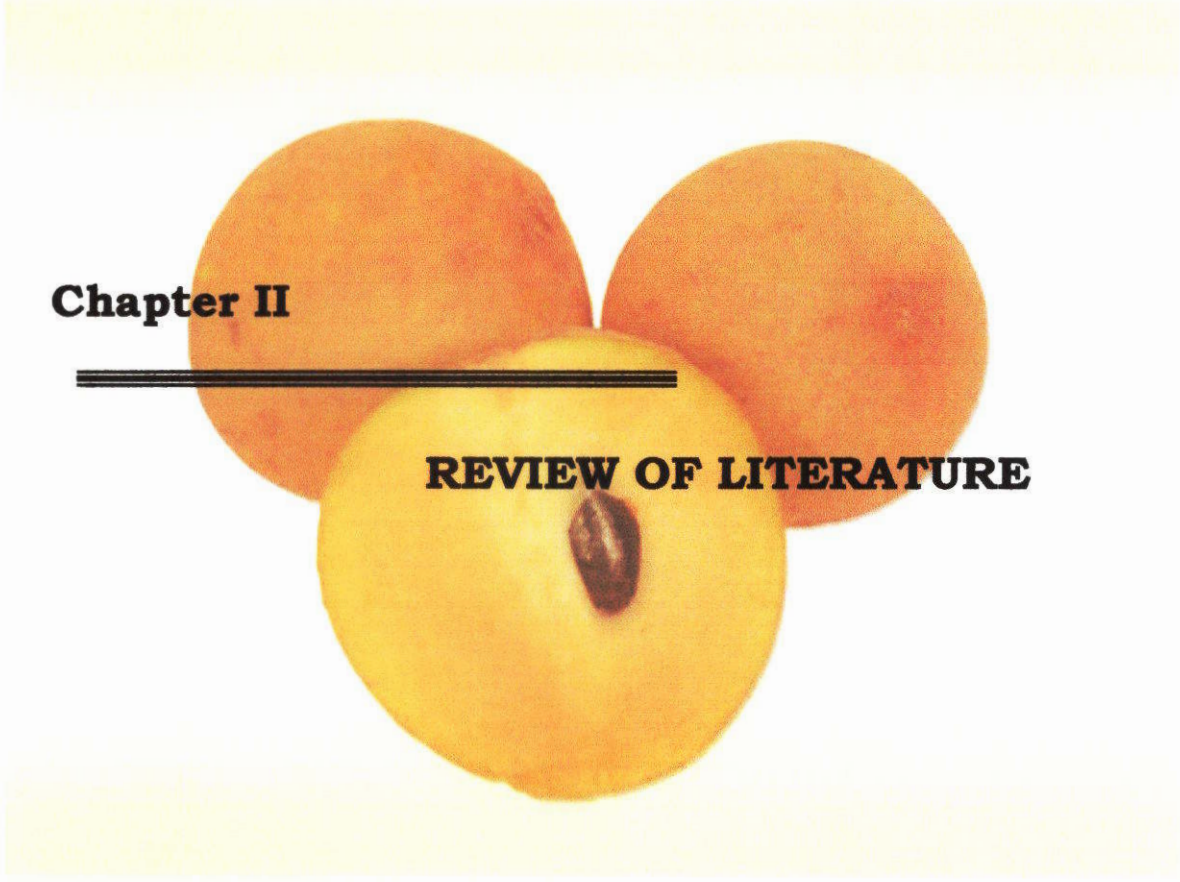
The fruit is a large ellipsoid berry, 4–8 cm in diameter, very much resembling a smooth-skinned potato and containing two to five seeds. Inside, its flesh ranges from a pale yellow to an earthy brown color with a grainy texture akin to that of a well-ripened pear. The fruit has a high latex content and does not ripen until picked. The fruit has an exceptionally sweet malty flavor. Many believe the flavor bears a striking resemblance to caramel. The unripe fruit is hard to the touch and contains high amounts of saponin, which has astringent properties similar to tannin, drying out the mouth. (Royen, *et al., 2009)*

The trees can only survive in warm, typically tropical environments, dying easily if the temperature drops below freezing. From germination, the sapodilla tree will usually take anywhere from 5–8 years to bear fruit. The sapodilla trees yield fruit twice a year, though flowering may continue year round. (Ali, *et al., 2010).*The sapote (*Pouteria sapota*), which originates from the lower parts of Central America, is a fruit-tree with tree pollination, which generally multiplies by seed. Its fruit may be eaten raw or green and the flesh is used to make jams, icecreams and sauces; when cooked, it can be an acceptable substitute for apple puree and may also be used in confectionery.(Chaughule, *et al.,* 2002). Chemical analysis shows that 100 g of sapote flesh contains 65.6 percent water, 1.7 g of protein. 0.4 g of fat, 31.1 g of carbohydrates, 2 g of fibre, 1.2 g of ash, 40 mg of calcium, 28 mg of phosphorus, 1 mg of iron, 115 mg of vitamin A, 0.01 mg of thiamine, 0.02 mg of riboflavin, 2 mg of niacin and 22 mg of ascorbic acid. (Brito and Narain, 2002)

In some parts of Mesoamerica, ground sapote seeds are used to give chocolate a bitter flavour and characteristic aroma; in Costa Rica, they have been used as a linen starch. In Guatemala and El Salvador, the oil from the seed is used as a skin tonic, to prevent baldness, to reduce muscular pain and to treat rheumatic ailments. (Moore & Steam, 2009)

Bangladesh is one of the over populated country in the world where most of the people live below the poverty line. It is difficult to fulfill their nutritional demands. Most of the exported fruits are expensive and due to this it is not possible to consume such types of fruits by all people. To meet the nutritional demand of the people of Bangladesh, sapota can play a vital role as a source of vitamins, minerals and other nutrients. As it grows in our country so it is possible to take it at a cheap rate. The climate of Bangladesh is suitable for sapota production but it is not cultivated widely. By determining the physical and chemical characteristics of this fruit it can be possible to obtain its nutritive value and other characteristics.The discussion made above indicated that giving attention to increase the production of sapota in context of Bangladesh is very essential. Unfortunately, the number of mentionable experiment on this fruit is very few in the country. So the present study was undertaken with the following objectives:

1. To study the physical properties of sapota.
2. To analyse the chemical composition of sapota to understand the nutritional facts.



Chapter II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Sapota (*Achras sapota.*) is an important fruit crop of our country. The highest sapota growing countries in India, Pakistan , Southern Mexico, Central America and the Caribbean. Sapota is considered as one of the most important and nutritious fruits that has gained commercial importance over the years because of its various uses. It is a fruit, being a good source of carbohydrates, minerals, vitamin A, Vitamin C, pectin and alkaloids. Bangladesh produces a huge quantity of fruits annually. Sapota is also an important fruit grown almost throughout Bangladesh. The production of sapota at Khulna, Josshore and Chittagong is famous for its growth and fruiting. (Hallwell *et al.,* 1992). Although sapota is one of the most important tropical fruit, a very little study has so far been made on its physico-chemical characteristics of sapota. A review of the available information relating to the present study is presented below.

Health benefits of sapota: The sapota juice can be used as a nutritional and nutraceutical product, which is a rich source of polyphenols. The multifunctional properties exhibited by the sapota juice can be used as a health-promoting beverage. Sapodillas are available all around the season in the markets. Harvesting is usually done by plucking each fruit gently as in mango. It is often difficult to tell when a sapodilla is ready to harvest. Mature fruit appears brown and easily separates from the stem without leaking of the latex. Scratch the fruit to make sure the skin is not green beneath the scurf. In the store, buy fresh sapodilla with smooth intact skin and without cuts/cracks, bruises or wrinkles. Mature but *unripe* fruits must be kept at room temperature for 7 to 10 days to ripen. Firm, ripe sapodillas can keep well for several days in the home refrigerator, and at 35° F, they can be kept for 6 weeks. The fruit is usually consumed fresh without any additions. Sapota, also called chiku, is a kind of fruit mainly grown in India due to its potent health benefits. In Guatemala, Mexico and other nations, sapota is grown commercially for making chewing gum. Consumption of sapota is recommended in herbal medicine as it is also thought to have innumerable medicinal uses. Further below are some of the major benefits of sapota.

Antioxidant vitamins: Sapota comprises of sufficient antioxidant vitamins such as vitamin A and vitamin C. Vitamin A helps to ensure proper vision and it is vital for maintaining healthy skin and mucus membranes. High intake of natural sources of vitamin A like

sapota is believed to offer protection from oral cavity and lung cancer. Similarly, vitamin C assists the body to develop a resistance against pathogens and destroy free radicals.

Tannins: Sapota contains the polyphenol compound tannin, which has been shown to have powerful antibacterial, anti-parasitic and antiviral effects. Actually, tannins have several beneficial applications medicinally where they act like remedies for hemorrhoids and diarrhea.

Fiber: Fiber is a key part of a good nutrition as it benefits the body in several ways. Sapota has lots of dietary fiber that assist to alleviate constipation episodes. The fiber also helps to protect mucous membranes present in the colon from the cancer inducing toxins through binding firmly to them.

Highly nutritious: Fresh sapota fruits are great sources of several nutrients and minerals like copper, iron, pantothenic acid and niacin. These nutrients are important for ideal health because they are involved in several metabolic body processes as enzyme cofactors.

Anti-inflammatory properties: Tannins found in sapota fruit have anti-inflammatory properties and assist to eliminate health conditions like IBS and erosive gastritis.The high fiber amounts present in sapota may cause stomach problems like gas, especially when consumed in high amounts.

The more benefits are:

- Sapodilla is rich in dietary fiber (5.6 g/100g), which makes it a good bulk laxative. The fiber content helps relieve constipation episodes and also helps protect the mucous membrane of the colon from cancer causing toxins by firmly binding to them.
- The fruit is rich in antioxidant poly-phenolic compound tannin. Tannins are a complex family of naturally occurring polyphenols that neutralize acids by precipitating proteins. Research studies found that tannins have shown to have potential anti-inflammatory, antiviral, anti-bacterial and anti-parasitic effects. Hence, these compounds have many useful medicinal applications such as anti-diarrheal, hemostatic (stops bleeding) and as a remedy for hemorrhoids.

- Furthermore, the anti-inflammatory effect of tannins help limit conditions like erosive gastritis, reflux-esophagitis, enteritis and irritating bowel disorders. Some other fruits that are rich in tannins include pomegranate, persimmon, grapes..etc.
- Sapota contains good amount of antioxidant vitamins like vitamin C (24.5% of recommended daily intake per 100 g of fruit) and vitamin A. Vitamin A is essential for vision. It is also required for maintaining healthy mucus membranes and skin. Consumption of natural fruits rich in vitamin A known to protect from lung and oral cavity cancers. So also, consumption of foods rich in vitamin C helps body develop resistance against infectious agents and scavenge harmful free radicals.
- Fresh ripen sapodilla are good source of minerals like potassium, copper, iron and vitamins like folate, niacin and pantothenic acid. These compounds are essential for optimal health as they involve in various metabolic processes in the body as cofactors for the enzymes.

Table A: below for in depth analysis of nutrients:

Sapota (*Achras sapota*), fresh, Nutritive value per 100 g. (Source: USDA National Nutrient data base)

Principle	**Nutrient Value**	**Percentage of RDA**
Energy	83 Kcal	4%
Carbohydrates	19.9 g	15%
Protein	0.44 g	<1%
Total Fat	1.10 g	3.5%
Dietary Fiber	5.3 g	14%
Vitamins:		
Folates	14 mcg	3.5%
Niacin	0.200 mg	1%
Pantothenic acid	0.252 mg	5%
Pyridoxine	0.037 mg	3%
Riboflavin	0.020 mg	1.5%
Thiamin	0.058 mg	5%

Principle	Nutrient Value	Percentage of RDA
Vitamin A	60 IU	2%
Vitamin C	14.7 mg	24.5%
Electrolytes:		
Sodium	12 mg	1%
Potassium	193 mg	4%
Minerals:		
Calcium	21 mg	2%
Copper	0.086 mg	9%
Iron	0.80mg	10%
Magnesium	12mg	3%
Phosphorous	12 mg	2%
Zinc	0.10 mg	1%

2.1 Physical Characteristics

Size of the fruit that major diameter of sapota (cricket ball variety)in various weights was found to be in the range of 4.85cm to 8.35cm,similarly intermediate diameter 4.59 to 7.71cm, and minor diameter between 3.91 to 8.48cm.According to the standard for fruits and vegetables. **(Mohensin, 1996).**

It was observed that sphericity value of sapota fruit ranged from 0.91 to 0.98 and an average of 0.95.This value being closer to one, it was to be inferred that the fruit could considered as spherical object. This explains the ease of rolling of the fruit on the grader. The fruit weight varied from 42.1g to 290.5g.The variation in the weight of the fruit was in agreement with.**(Laxminarayana , 1980).**

Adhaoo (1976) reported that surface area of sapota ranged from 45 – 290cm2.The angle of repose of sapota fruit in their natural heaped position was found to be 24 degrees. This property was useful in finalizing the angle for singulation unit, since singulation unit is mounted at an angle of 40 degrees to horizontal there was no rollback of fruits during carrying. The moisture content on wet basis for sapota fruit was found to be 77.7%.

Moore & Steam (2009) stated that sapota may be round, ovoid or elliptic, often bluntly pointed at the apex, varies from 3 to 9 in (7.5-22.8 cm) long, and ranges in weight from 1/2 lb to 5 lbs (227 g-2.3 kg).

Morton and Miami (1987) observed that sapota may be nearly round, oblate, oval, ellipsoidal, or conical; varies from 2 to 4 in (5-10 cm) in width. When immature it is hard, gummy and very astringent. Though smooth-skinned it is coated with a sandy brown scurf until fully ripe. The flesh ranges in color from yellowish to light- or dark-brown or sometimes reddish-brown; may be coarse and somewhat grainy or smooth; becomes soft and very juicy, with a sweet flavor resembling that of a pear. Some fruits are seedless, but normally there may be from 3 to 12 seeds which are easily removed as they are loosely held in a whorl of slots in the center of the fruit. They are brown or black, with one white margin; hard, glossy; long-oval, flat, with usually a distinct curved hook on one margin; and about 1/4 in (2 cm) long.

Brito and Narain (2002) observed that the average diameter and length of the half-ripe sapota fruit were 7.5 and 6.4 cm, respectively, and there was a significant difference in these parameters between the mature green and the half-ripe stages (Table 2). There was a greater increase in diameter than in the length during the change from mature green to half-ripe. The fact that the diameter was greater than the length classifies the fruit more towards round in shape. In a total of twenty-three cultivars studied, only six had round fruits, and all these six fruits had a higher standard deviation than the fruits of cultivar Itapirema-31 (Lakshminarayana & Rivera, 1979; Moura *et al.,* 1983). From the mature green to the half-ripe stage there was a great increase in the weight of the fruit, from an average of 91.9 to 198.4 g. Fruits of Itapirema-31 were smaller than the three Mexican cultivars (Lakshminarayana & Rivera, 1979), but the standard deviation of the Brazilian fruit was lower which leads to a more uniform fruit weight.

The large sized fruits along with good quality, were produced during the winter season, the fruits of monsoon season were inferior in quality. In general, the variety CO-2 is moderate with respect to the physical characters of sapota fruits. However, the variety Kalipatti, which is commercially adopted and grown on large scale by farmers of south Gujarat region because of its high yielding potentiality and good quality with longer shelf life of fruits than all other varieties. **(Vahora *et al.*, 2009)**

2.2 Chemical Characteristics

Chemical composition analysis of sapota juice revealed that it is one of the rich sources of sugars, proteins, ascorbic acid, phenolics, carotenoids and minerals like iron, copper, zinc, calcium and potassium. Apart from the nutritional components just given, sapota juice

showed potential antioxidant activity against 1,1-diphenyl-2- picrylhydrazyl free radicals and superoxide radicals. Sapota juice potentially inhibited the free radical-mediated lipid peroxidation in a liposome model system. Total reducing-power assay revealed the potential reducing power of sapota juice. The multiple radical-scavenging potential of sapota juice was found to be due to its nutraceutical components, viz., phenolics, carotenoids and ascorbic acid. **(Kulkarni *et al., 2006*)**

Lynch (2005) observed that in terms of fruit quality, the acids and sugars are important components, which provide characteristic taste and flavor to fruits and their products. The quality of the sapota fruit juice is often expressed in terms of sweetness-to-sourness ratio (Brix/acid). Titrable acidity (as percent citric acid) of sapota juice was found to be about 0.16-0.01. Titrable acidity is the measure of the total or potential acidity, i.e., total number of acid molecules, both protonated and unprotonated. The lesser the titrable acidity, the lesser will be the sourness. One more quality index of fruit, i.e., the TSS content of sapota, was found to be 20.68-1.2%. The high Brix/acid ratio (129.25) rendered the sapota as one of the sweetest fruits. Sapota juice was found to contain moderate amount of sugar and protein, and it was also found to be a good source of ascorbic acid, carotenoids and phenolics .Ascorbic acid, carotenoids and phenolics were reported to have many health beneficial properties. Apart from the nutritional components just given, sapota juice was found to be a good source of transition metals, viz., iron, copper and zinc. The presence of these transition metals is one of the important nutritional qualities of sapota juice, because deficiency of transition metal ions continues to be the most prevalent nutritional deficiency disorder in the world, affecting an estimated two billion people, most of who live in developing countries.

Kwong *et al.* (2004) stated that Sapota juice is a good source of iron, copper, zinc, calcium, potassium which are most essential mineral requirements for the normal functioning of a biological system.

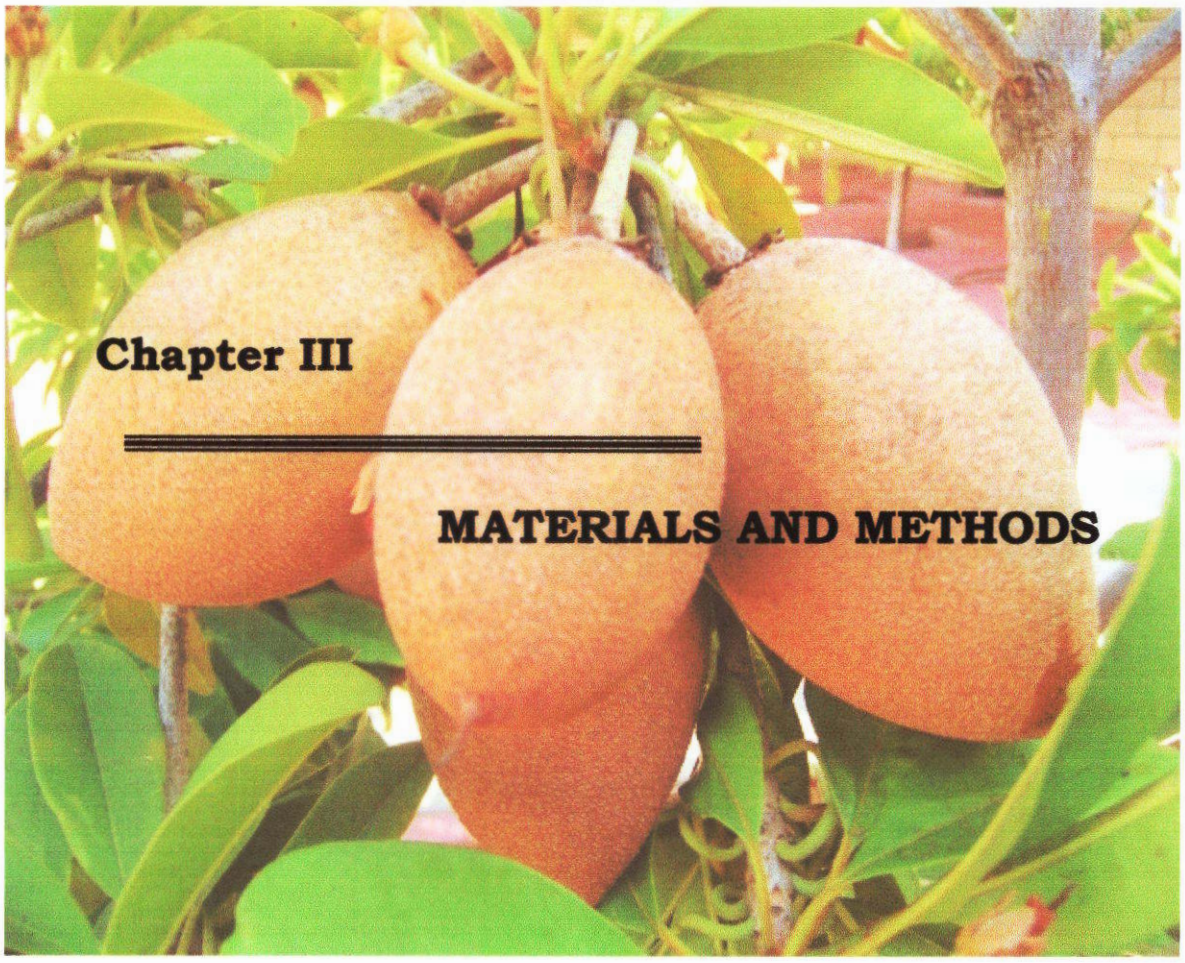
Genotypes of sapote were characterized based on chemical characteristics of fruits. Variability of sapota attributed to chemical characteristics of fruits. Those were the chemical compositions obtain are titratable acidity (TA), protein, total soluble solids (TSS), TSS to TA ratio and TSS to pH ratio. Fruit weight, mesocarp thickness, and the ratio of total soluble solids to titratable acidity were dominant in the first function; and fruit weight and mesocarp thickness were dominant in the second. These morphological variables could be used for selecting sapote mamey trees with uniform fruit quality for either direct consumption or processing. **(Mccarty, 2004*)***

Mamey sapote (*Pouteria sapota*) is a tropical species from the Sapotaceae family native to Mexico and Central America. Its tree produces an edible climacteric fruit, whose weight can range from 250 to 900 g. The flesh is soft, comprises about 78% of the fruit, and has high sugars to acidity ratio, which gives it a sweet taste when ripe. Because of current public interest to consume products that promote health, the aim of the work was to characterize soluble phenolic content and antioxidant activity in mamey sapote fruits from Chiapas, Mexico, at different maturity stages. Storage at 12 (± 1) °C was conducted for 18 d. When fruits ripened firmness flesh varied, in average, from 41.8 to 3.0 N, soluble solids content from 17.7 to 28.1 °Brix, hue angle from 56.4 to 46.3°, and lightness from 67.3 to 42.0. Antioxidant activity, expressed through the IC_{50} parameter, remained practically unchanged and showed an average value of 12.9 µg/mL. Based on phenolic composition the mamey sapote fruit may constitute a good source of antioxidant compounds (**Orwa *et al.*, 2009**).

Chemical compounds in fruits and vegetables have gained great importance in the last few years because of the increasing evidence suggesting their antioxidant and prevention of chronic diseases. Carotenoids, phenolics, flavonoids, and vitamins E and C, are among these phytochemicals. Several fruits have been characterized so far for their antioxidant and health properties but there is still limited information on fruits from the tropic. Total carotenoid content was 1127.9 µg β-carotene/100 g fw with β-carotene being the main contributor, in addition to lutein, and violoxanthin. Concentration of δ-tocopherol was 360.0 µg/100 g fw. Infact, sapota fruit is a good source of carotenoids and its inclusion in the diet is recommended.(**Yahia *et al.*, 2010**)

Shui *et al.* (2004) reported that the mature ripe sapota is granted as a tasty fruit. This fruit is also used to make jelly, jam, condiment etc.

From the above review of literature it is revealed that a wide variation is found in respect of physico-chemical characteristics of sapota. But less number of works has been done on these topics of the fruit in Bangladesh. Therefore the present study was undertaken to evaluate the physico-chemical properties from sapota germplasm available in the south western region of Bangladesh.



Chapter III

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiment on physico-chemical characteristics from sapota was carried out during the period from February to July, 2011. In the study, 30 germplasm were selected from south western region of Bangladesh. Three fruits from each of the germplasm were randomly collected and brought to the Horticulture Laboratory of the Agrotechnology Discipline of Khulna University, Khulna for laboratory analysis.

3.1 Experiment No. 1

Study on physico-chemical characteristics of sapota.

3.2 Experimental Design

The experiment was laid out in Completely Randomized Design (CRD) with three replications.

3.3 Experimental Materials

Thirty germplasm selected as the experimental materials for the investigation. Ninety mature fruits, 3 from each plant were collected for the study. The list of germplasms with their location and data are presented in Appendix IX.

3.4 Methods of Studying Parameters

The genotypes were characterized and evalulated based on physical and chemical parameters.

3.4.1 Organoleptic Tests of sapota

A panel of five final year students of Agrotechnology Discipline was selected randomly and invited to Molecular Horticulture Laboratory to taste physical properties of 30 germplasm of sapota. One organoleptic test sheet was supplied to each student. Slices of three sapota fruits of each germplasm were supplied to each student. They recorded their personal remarks/feelings about juiceness, softness, flavor, sweetness, sourness, and bitterness on the supplied sheet.

3.4.2 Physical Parameter

3.4.2.1 Determination of weight of fruits

The fruit weight was measured by an electric balance. The fruits were cleaned and weighted by keeping the fruit on the chamber of the balance.

3.4.2.2 Determination of size of fruits

Length and width of the fruits were determined by a slide calliper.

3.4.2.3 Determination of weight of skin of fruits

Skin weight was measured by an electric balance. At first, the balance was adjusted to zero mark. By using a sharp knife the skin was peeled out from fruit. Then the weight of skin was weighted by keeping it in the chamber of balance and the reading was taken in gram (g).

3.4.2.4 Determination of weight of stone of fruits

The weight of stone of fruit was measured by an electric balance. At first, the balance was adjusted to zero mark. After separating the skin from the fruit, by using a sharp knife the stone was separated from the fruit pulp. Then the weight of the stone was estimated by keeping it in the chamber of balance and the reading was taken in gram (g).

3.4.2.5 Determination of weight of edible portion of fruits

The weight of edible portion of fruit was measured by an electric balance. At first, the balance was adjusted to zero mark. After removing the skin and stone from fruit the remaining edible portion (pulp) was estimated by keeping it in the chamber of balance and the reading was taken in gram (g).

3.4.2.6 Determination of weight of non-edible portion of fruits

Weight of non-edible portion of the fruit was measured by subtracting the weight of edible portion from the total weight of fruit. This weight was measured in gram (g).

3.4.2.7 Determination of percentage of edible portion of fruits

The percentage of edible portion of fruit (pulp) was calculated by the following formula:

$$\text{Percentage of edible portion} = \frac{\text{Weight of edible parts}}{\text{Weight of whole fruit}} \times 100$$

3.4.2.8 Determination of percentage of non-edible portion of fruits

The percentage of non-edible (skin and stone) portion of fruit was calculated by the following formula:

$$\text{Percentage of non-edible portion} = \frac{\text{Weight of non-edible parts}}{\text{Weight of whole fruit}} \times 100$$

3.4.3 Chemical characteristics

The methods for the estimation of pH, TSS, Titrable acidity, vitamin C, Carotenoids, Anthocyanin and Flavonoids of fruit pulp were followed as described by Mazumdar and Majumdar (2001) and Saini *et al.* (2006). The data were analyzed by fresh weight basis.

3.4.3.1 Determination of pH of fruit pulp

The pH of fruit pulp was measured by a desktop pH meter (The pH of the fresh juice was measured using Control Dynamics pH meter calibrated with standard buffer pH 7.)

Preparation of standard buffer solution

pH 7 and pH 4 buffer tablet was dissolved in water and made up the mark of 100 ml with distilled water.

Extraction of fruit juice

For the determination of pulp pH, 5g of fresh pulp was taken in a conical flask with 10 ml of distilled water. Then the pulp was crashed by using blender and extract was filtrated through two layer of cloth.

Procedure

The standard buffer solution of pH 7 was taken into a clean and dry beaker. The electrode assembly of the pH meter was dipped into the solution. The temperature correction knob was set to 28°C and the fine adjustment was made by asymmetry potential knob to pH 7.

After washing with distilled water the electrode assembly was dipped into a solution of standard pH 4 and adjusted to the required pH by fine asymmetry potential knob. The electrode assembly was raised, washed twice with distilled water then rinsed with sapota juice and finally it was dipped into the juice of sapota and pH was recorded from the meter.

3.4.3.2 Determination of Total Soluble solids (TSS)

Equipment:

Hand refractometer

Procedure

TSS content of the juice was determined as percent °Brix with a digital refractometer (ATAGO RX-5000) calibrated with distilled water.A drop of juice from the pulp of sapota was placed on the prism of the refractometer and percentage of total soluble solid was obtained from direct reading. Temperature correction was made as described by Ranaganna (2001).

3.4.3.3 Determination of titratable acidity(T-acidity) in fruit pulp

Titrable acidity was determined by AOAC (1990) method. In brief, about 2–3 g of sapota juice was titrated against 0.1-N NaOH with phenolphthalein indicator until a pink color persisted.

Reagents:

A. Sodium hydroxide (NaOH): 0.1 normality (N).

B. Indicator: Phenolphthalein ($C_{20}H_{14}O_4$) [approx. 0.5 % in 80% ethanol (W/V)].

Equipment:

Ten millilitre pipette, 25 ml burette, small glass funnel, dropper, blender, 250 ml measuring cylinder, burette stand and beaker.

Procedure:

- 30 g of tissue sample by weight was taken. This was extracted with distilled water by through crushing in blender. Extract was filtered and the filtrate was made upto 100 ml with distilled water.

- 15 ml of aliquot was taken into a conical flask. Three to four drops of phenolphthalein solution were added to this aliquot and shaken well.
- A burette was filled with the sodium hydroxide solution after washing and rinsing.
- Titration was done and end point was determined by the appearance of pink colour and its persistence for at least 10 to 15 seconds.

Calculation

In term of citric acid 1 ml of 0.1N NaOH solution can neutralize 0.064 g of citric acid. Therefore percentage of titratable acidity in the sample as equivalent of citric acid

$$\% \text{ Titrable acidity} = \frac{d \times 0.064 \times c}{a \times b} \text{ X } 100$$

Where,

a = Weight of sample.

b = Volume of aliquot taken for examination.

c = Volume made with distilled water.

d = Average burette reading for sample.

Observation Chart

Serial No	Initial burette reading	Final burette reading	Volume of alkali consumed
1			
2			
3			

3.4.3.4 Determination of vitamin C (ascorbic acid) content

Principle:

Titrimetric estimation of Vitamin-C is conventionally done using 2,6 dichlorophenol indophenol dyesolution. This dye is blue in alkaline solution and red in acidic solution. Ascorbic acid reduces the dye to a colourless form. Reaction is quantitative and specific for ascorbic acid at pH 1.0-3.5

Apparatus:

- Volumetric flask 250 ml,
- Conical flask 250 ml,
- Beaker 150 ml,
- blender,
- Water bath
- Burette 250 ml and
- Pipette.

Reagents used for the estimation of vitamin C content

(A) Metaphosphoric acid (HPO_3): 3 percent in distilled water (W/V).

(B) 2,6- dichlorophenol indophenol ($C_{12}H_6C_2NNaO_2$, $2H_2O$) solution 0.025 percent (50 mg 2,6- dichlorophenol indophenol is weighed and taken in a beaker. 42 mg sodium bicarbonate (Na_2HCO_3)is added to it. It is then dissolved in little amount distilled water and the volume is made upto 200 ml with distilled water).

(C) Standard ascorbic acid ($C_6H_8O_6$) solution: 0.01 percent in 3 percent metaphosphoric acid (W/V).

Preparation of Standard ascorbic acid solution: 0.01 percent in 3 percent met phosphoric acid (w/v).

Standardization of Dye solution: The dye solution is needed to be standardized simultaneously. For this 5 ml of standard ascorbic acid solution was taken in a clean beaker to which 5 ml of 3% metaphosphoric acid solution was added with the help of a

pipette. This solution was titrated against the dye till a faint pink colour was obtained which persisted for more than 15 seconds.

Estimation of ascorbic acid

30 g of fruit flesh was weighed and blended it with equal weight of 3% Meta phosphoric acid for 3 to 4 minutes. 15 g of this slurry was used in a 100 ml volumetric flask and volume was made by adding 3% Meta phosphoric acid. This juice was filtrated through a fast filter paper (Whatman No. 42).

Titration

The burette was filled with standardized 2, 6-dichlorophenol; indophenols dye reagent.10 cc of filtered solution was taken in a conical flask and titrated immediately against standard dye solution, till faint pink color was observed which persisted for not less than 15 seconds.

Procedure:

1. Known amount of tissue sample by weight is taken. This is extracted with 3 percent metaphosphoric acid (Reagent-A) by thorough crushing. Extract is filtered and filtrate is made upto a known volume with 3 percent metaphosphoric acid.
2. A known volume of aliquot is taken in a conical flask burette is filled with in indophenol dye solution (Reagent-B) and titration is done. End-Point is determined by the appearance of pink colour which should persist for at least 15 seconds.
3. Standardization of the dye- solution: The dye solution is needed to be standardized simultaneously. For this, 5 ml of standard ascorbic acid solution (Reagent-C) is taken in a conical flask and to this; 5 ml of 3 percent metaphosphoric acid solution is added. Both are thoroughly mixed by shaking and are titrated against indophenol dye solution to get the pink colour end-point and persistence for few seconds.

Observation Chart

Serial No.	**Initial burette reading**	**Final burette reading**	**Volume of alkali consumed (ml)**
1			
2			
3			
Mean			

Calculation:

$$\text{The dye factor (d)} = \frac{0.5}{\text{Average burette reading for standardization of dye solution}}$$

Vitamin-C content in the sample is determined by the following Formula.

$$\text{Vitamin-C (mg per 100g)} = \frac{e \times d \times b}{c \times a} X\ 100$$

Where,

a = Weight of sample

b = Volume made with metaphosphoric acid

c = Volume of aliquot taken for estimation

d = Dye factor

e = Average burette reading for sample

3.4.3.5 Determination of carotenoids of fruit pulp

Total carotenoid content was determined by spectrophotometric method described earlier by Ranganna (2001).

Materials

Acetone AR grade 80%

Procedure

1. 1 gm of finely cut fruit sample was weighed by an electric balance.
2. The fruit sample was mixed well into a clean mortar.
3. The tissue sample was grinded to a fine pulp with addition of 20 ml of 80 % acetone.
4. It was centrifuged at 5000 rpm for 5 minutes and transferred the supernant to a 100ml of volumetric flask.
5. The residue was grinded with 20ml of 80% acetone, centrifuged and transferred the supernant to the same flask.
6. The procedure was repeated until the residue was colourless. The pestle and mortar were washed thoroughly with 80 % acetone and the clear washing was collected in the flask.
7. The volume was made to 100 ml with 80% acetone.
8. The absorbance was read at 510 nm and 480 nm against blank.

Calculations

$$mg\ carotenoids\ /\ g\ tissue = 7.6(A.480) - 1.49(A.510) \times \frac{V}{1000 \times 10}$$

Where,

A= Absorbance of the specific wave length.

V= Final Volume of the Carotenoids in 80% acetone

W= Fresh weight of the tissue extracted

3.4.3.6 Determination of anthocyanin of fruit pulp

Principle

Anthocyanin is extracted with ethanolic-hydrochloride and the intensity of the colour appeared is measured calorimetrically. From the reading, the amount of the pigment present is determined.

Reagents

(A) Ethanol: 95%

(B) Hydrochloric acid (HCl): 1.5 N.

(C) Ethanol -hydrochloric acid mixture: It was prepared by mixing 85 parts of Reagent A and 15 parts of Regent B by volume.

Procedure

1. 5 g of tissue sample by weight was taken. This was extracted with ethanol hydrochloric acid mixture. It was allowed to stand overnight at a temperature of about 4°C.

2. After extraction, the mixture was filtered through filter paper (Whatman No.1). The extraction was repeated for maximum recovery of the pigment.

3. The extract was then made up to 15 ml with the solvent.

4. 15 ml of aliquot from the above extract was taken. It was filtered through fine (milli-pore) filter paper.

5. The filtered aliquot was maintained in darkness for about 2 hours with cover of the container.

6. This was then made up to 25 ml with the solvent (for colour measurement). The optical density (O.D.) value of the solution was then measured through 535nm wavelength in a colorimeter against blank.

Calculation

$$Total\ Asbsorbance\ Value\ of\ the\ sample\ (per\ 100g) = \frac{e \times b \times c}{d \times a} \times 100$$

Where,

a = Weight of sample

b = Volume made for colour measurement

c = Total volume made

d = Volume of aliquot taken for estimation

e = Volume for 535 nm

Anthocyanine (mg/100g) = Total absorbance/98.2

3.4.3.7 Determination of flavonoids of fruit pulp

Reagent

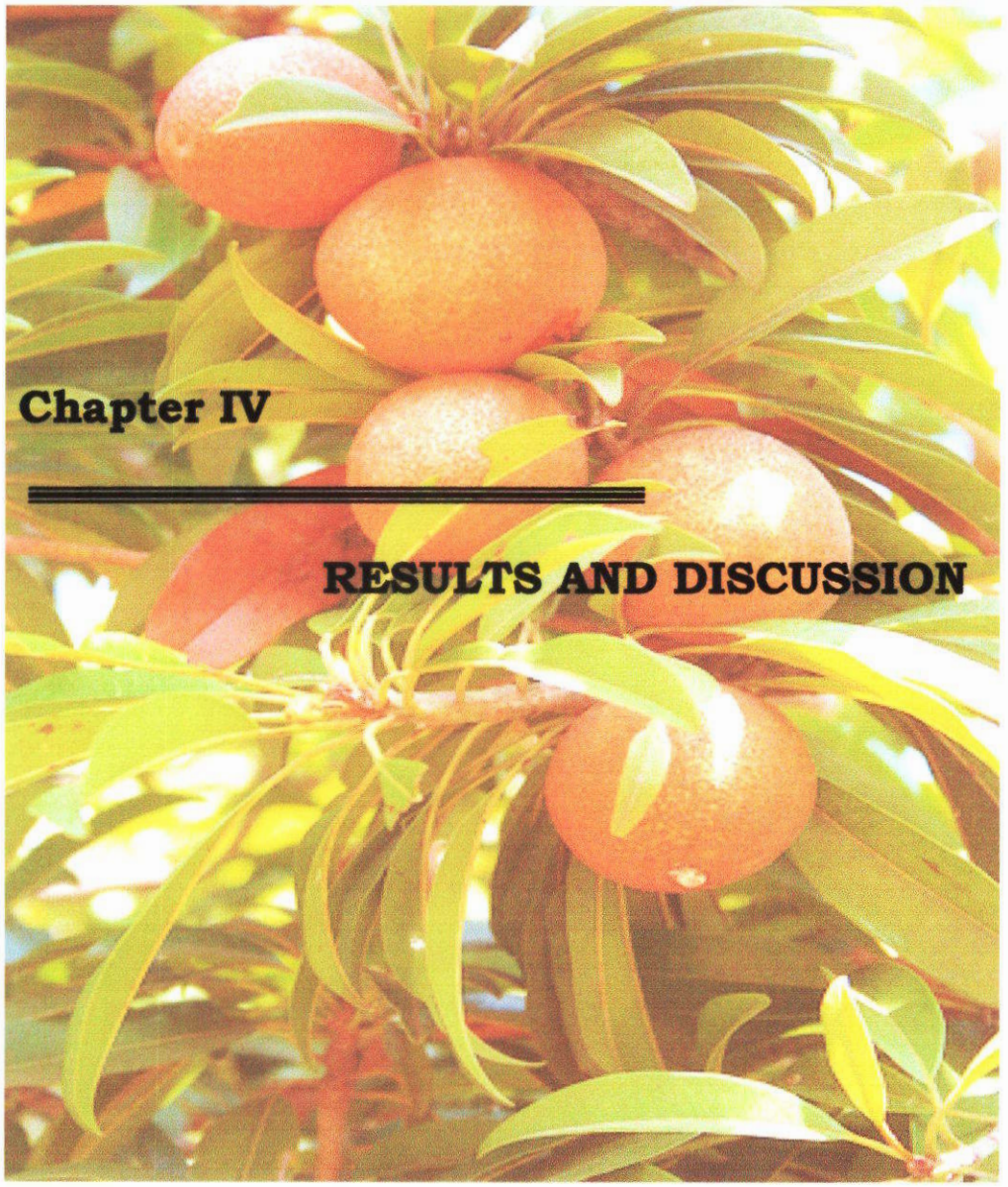
(A) 80% methanol.

Procedure

1. 10 g of sample was taken and crushed finely.
2. 100 ml of 80% methanol was added and kept it in a water bath for 10 hours at 40^0C.
3. The whole solution was filtered through a filter paper.
4. The filtrate was transferred to a crucible and then evaporated to dryness over a water bath at room temperature.
5. The final finding was weighed as flavonoids.

3.5 Statistical Analysis

The collected data were statistically analyzed and means were compared by ANOVA and Duncan's Multiple Range Test (DMRT).



Chapter IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results of the study in physico-chemical characteristics of sapota are presented and discussed in this part.

4.1 Experiment No. 1: Study on physico-chemical characteristics of Sapota

Fruits of 30 sapota germplasm were studied on the basis of physical and chemical characteristics and the results are presented and discussed under the following headings.

4.1.1 Organoleptic Tests of sapota

Data on Organoleptic Tests of sapota are presented in (Table 1).

4.1.1.1 Juiciness of sapota

Significant differences were found among 30 germplasm in respect of juice of fruit. The highest juices (3.75) was found in germplasm No. 51,53,54,59,63,66,67,70,72,75,80 which are statistically similar with that of germplasm No. 56,58,60,69,73,78.while the lowest juiciness (1.25) fruit was measured from germplasm No.71. (Table 1).

Table: 1 Organoleptic Tastes of sapota

Sl no	GP no	Juciness	Softness	Flavor	Sweetness	Sourness	Bitterness
1	51	3.75a	3.25a	2.75abcd	3.00ab	3.50ab	2.50bcd
2	52	1.50de	3.00a	3.25abc	3.75ab	3.50ab	3.50abc
3	53	3.75a	1.50b	2.75abcd	2.75ab	3.25ab	3.75ab
4	54	3.75a	3.75a	3.75ab	4.00a	3.90b	3.75ab
5	55	2.00bcde	2.75ab	1.50d	2.00ab	3.25ab	3.50abc
6	56	3.25ab	3.50a	3.00abcd	3.75ab	3.25ab	1.75d
7	57	2.00bcde	2.50ab	2.50abcd	1.75b	3.00ab	3.50abc
8	58	3.25ab	3.25a	2.75abcd	2.25ab	4.00b	2.25cd
9	59	3.75a	3.50a	4.00a	3.75ab	3.75ab	4.00a
10	60	3.25ab	3.25a	2.75abcd	2.25ab	3.75ab	3.50abc
11	61	1.75cde	2.75ab	3.00abcd	3.25ab	3.00ab	3.50abc
12	62	3.00abc	3.00a	3.25abc	3.25ab	3.50ab	3.50abc
13	63	3.50a	2.75ab	3.00abcd	2.25ab	3.25ab	4.00a
14	64	2.50abcde	3.25a	3.00abcd	3.25ab	3.25ab	3.25abc
15	65	2.75abcd	2.50ab	3.25abc	3.00ab	3.25ab	3.75ab
16	66	3.50a	2.75ab	3.75ab	1.75b	3.00ab	4.00a
17	67	3.50a	3.50a	3.75ab	3.50ab	3.00ab	3.50abc
18	68	2.75abcd	3.00a	3.25abc	3.00ab	3.25ab	3.75ab
19	69	3.25ab	2.75ab	3.75ab	2.25ab	2.75b	4.00a
20	70	3.75a	3.50a	3.75ab	3.50ab	3.75ab	3.75ab
21	**71**	**1.25e**	**3.25a**	**2.25bcd**	**3.25ab**	**3.50ab**	**3.75ab**
22	72	3.75a	3.25a	3.75ab	3.50ab	3.50ab	4.00a

Sl no	GP no	Juciness	Softness	Flavor	Sweetness	Sourness	Bitterness
23	73	3.25ab	3.25a	3.50abc	3.25ab	3.50ab	3.75ab
24	74	2.50abcde	3.25a	2.00cd	3.00ab	3.50ab	3.75ab
25	75	3.75a	2.75ab	3.75ab	1.75b	3.50ab	3.50abc
26	76	2.50abcde	2.75ab	2.25bcd	3.25ab	3.25ab	3.500abc
27	77	2.50abcde	2.75ab	2.00cd	3.25ab	3.75ab	3.75ab
28	78	3.25ab	2.50ab	3.75ab	2.25ab	3.00ab	3.75ab
29	79	2.75abcd	3.00a	3.25abc	2.50ab	3.50ab	3.25abc
30	80	3.75a	2.50ab	2.25bcd	2.25ab	3.25ab	4.00a
	Average	2.99	2.98	3.05	2.88	3.35	3.53
	Level of significance	0.01	0.01	0.01	0.01	0.01	0.01
	C.V %	21.53	5.71	7.82	26.64	18.37	22.98

4.1.1.2 Softness of sapota

Significant differences were found among the germplasm in respect of softness of fruit. Softness was found highest in germplasm No.51,52,54,56,58,59,60,62,64,67,68,70,72,73,74,

79 which are statistically similar with that of germplasmNo.55,57,61,63,69,78. The lowest softness of fruit was measured from germplasm No.53. (Table 1).

4.1.1.3 Flavor of sapota

Significant differences were found among the germplasm in respect of flavor of fruit. The highest flavor was found in germplasm No. 59 which was statistically similar with germplasm No. 54,66,57,61,67,69,70,72,75,78.while the lowest flavor fruit was measured from germplasm No.55. (Table 1).

4.1.1.4 Sweetness of sapota

Significant differences were found among the germplasm in respect of sweetness of fruit. The highest softness was found in germplasm No. 54 which was statistically similar with that of germplasm No.56,58,59,60,62,64,67,68,70,72,73,74,79 55,61,63,69,78.while the lowest sweet fruit was measured from germplasm No.57,66,75. (Table 1).

4.1.1.5 Sourness of sapota

Significant differences were found among the germplasm in respect of sourness of fruit. The highest sourness was found in germplasm No. 54 which was statistically similar with germplasm No.51,55,56,58,59,60,61,63,.62,64,67,68,70,72,73,74,78,79, while the lowest sweet fruit was measured from germplasm No. 69. (Table 1).

4.1.1.6 Bitterness of sapota

Significant differences were found among the germplasm in respect of sourness of fruit. The highest bitterness was found in germplasm No. 59,63,66,69,72 which was statistically similar with germplasm No.53,58,65,68,70 while the lowest bitter fruit was measured from germplasm No. 56. (Table 1).

4.1.2 Physical characteristics of sapota

4.1.2.1 Weight of individual fruits

The fruit weight was significantly varied among the germplasm. The germplasm No.80 was given the maximum fruit weight (94.39 g) which was statistically similar to germplasm No. 63 (92.13 g) while it was minimum in germplasm No. 65 (14.35 g) which was statistically similar to the germplasm No. 61 (21.84 g), No. 66 (24.10 g). Average fruit weight was found 60.31 g. (Table 2).

The present result fairly agrees with the report of **Shirol *et al.*, (2009), and Brito and Narain (2002).** They reported the average fruit weight of sapota was 56.60g and 60-90g.

Table 2. Physical Characteristics of Sapota

Sl No	GP no.	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Skin weight (gm)	Weight of stone (g)	Non edible portion (g)	Edible portion (g)	Non edible portion (%)	Edible portion (%)
1	51	83.65abcde	5.00a	5.18ab	9.06bcde	1.98bcde	11.04cde	72.62abc	13.16cdef	86.84abcd
2	52	71.94abcdefg	4.97ab	5.11abc	9.91bcd	1.94bcdef	11.86bcd	60.08abcd	16.46bcdef	83.54abcde
3	53	58.63defghi	4.66abcd	4.71abcd	6.48defg	1.73cdefg	8.21cdefg	50.41 bcde	14.21bcdef	85.79abcd
4	54	78.86abcde	4.39abcdef	5.19ab	6.49defg	1.77cdefg	8.26cdefg	70.60abc	10.72ef	89.28ab
5	55	69.86abcdefg	4.83abcd	4.87abc	8.24cdef	2.53b	10.76cdef	59.10abcd	15.51bcdef	84.49abcde
6	56	56.04efghi	4.60abcde	4.48bcd	6.02defgh	1.55defg	7.58efghi	48.47cdef	13.59cdef	86.41abcd
7	57	81.42abcde	4.75abcd	4.87abc	7.19cdefg	1.82bcdefg	9.02cdefg	72.40abc	11.07ef	88.93ab
8	58	47.94fghij	4.29cdef	4.40cd	6.42defg	1.91bcdef	8.33cdefg	39.60 defg	17.77bcde	82.23abcde
9	59	42.88ghijk	4.23def	3.71ef	5.87efgh	1.07g	6.94efghi	35.95defgh	17.11bcdef	82.89abcde
10	60	75.91abcdef	4.73abcd	5.00abc	6.56defg	1.08g	7.64defghi	68.27abc	10.40ef	89.60ab
11	61	21.84jk	3.56gh	3.12fg	2.38h	1.21efg	3.53i	17.88gh	16.28bcdef	81.63bcde
12	62	41.71ghijk	4.01efg	4.05de	6.10defgh	2.28bcd	8.32cdefg	35.45defgh	19.34abcd	84.72abcde
13	63	92.13ab	4.49abcde	5.33a	14.36a	3.65a	17.94a	74.30abc	19.25abcd	80.86bcde
14	64	29.37ijk	4.27cdef	4.56bcd	5.73efgh	1.19fg	6.88efghi	22.57fgh	25.20a	74.98ef
15	65	14.35k	3.42h	2.67g	2.41h	1.35efg	3.70hi	10.17h	25.92a	70.79f

Sl No	GP no.	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Skin weight (gm)	Weight of stone (g)	Non edible portion (g)	Edible portion (g)	Non edible portion (%)	Edible portion (%)
16	66	24.10jk	3.84fgh	3.18fg	3.65gh	1.58defg	5.23ghi	18.66gh	21.74ab	77.41def
17	67	44.90ghij	4.39abcdef	4.01de	6.08defgh	1.36efg	7.36efghi	37.27defgh	16.41bcdef	82.98abcde
18	68	65.04abcdefg	4.68abcd	4.58abcd	4.67fgh	1.48efg	6.06ghi	58.45abcd	9.31f	89.88ab
19	69	64.86abcdefg	4.46abcde	4.71abcd	6.35defgh	1.61defg	7.87cdefgh	56.71abcd	12.21def	87.35abcd
20	70	88.06abcd	4.69abcd	5.11abc	12.46ab	2.43bc	14.89 ab	73.27abc	17.29bcde	82.86abcde
21	71	59.65defgh	4.36bcdef	4.56bcd	4.61fgh	1.79bcdefg	6.35ghi	53.15bcde	10.73ef	89.04ab
22	72	69.83abcdefg	4.54abcde	4.47bcd	5.99defgh	1.39efg	7.36efghi	62.40abcd	10.75ef	89.15ab
23	73	58.46defghi	4.23def	4.41cd	4.89fgh	1.96bcdef	6.80efghi	51.55bcde	11.66def	88.17abc
24	74	**61.25cdefgh**	**4.38abcdef**	**4.65abcd**	**6.87cdefg**	**1.27efg**	**8.09cdefg**	**56.05bcd**	**13.25cdef**	**91.95a**
25	75	32.46 hijk	3.83fgh	3.60ef	4.74fgh	1.50efg	6.22ghi	25.83efgh	20.14abc	78.46cdef
26	76	**66.09abcdefg**	**2.55l**	**2.68g**	**6.48defg**	**1.31efg**	**7.74cdefghi**	**58.44abcd**	**11.71def**	**88.44ab**
27	77	63.37bcdefg	4.39abcdef	4.73abcd	5.30efgh	1.27efg	6.52fghi	56.69abcd	11.31ef	88.48ab
28	78	90.65abc	4.87abc	5.20ab	10.56bc	1.42efg	11.92bc	78.69ab	13.33cdef	86.59abcd
29	79	59.53defgh	4.77abcd	3.58ef	7.27cdefg	1.37efg	8.64cdefg	50.67bcde	14.54bcdef	85.09abcd
30	**80**	**94.39a**	**4.95ab**	**5.11abc**	**8.12cdef**	**1.32efg**	**9.45cdefg**	**84.89a**	**10.21ef**	**89.71ab**
	Average	60.31	4.37	4.39	6.71	1.67	8.35	52.02	15.02	84. 95
	Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	C.V %	21.53	5.71	7.82	26.64	18.37	22.98	22.99	21.56	4.94

Note. In a column figures having similar letters do not differ significantly whereas figures having dissimilar letters differ significantly as per DMRT

4.1.2.2 Length of fruit

Significant differences were found among the 30 germplasm in respect of length of fruit. The longest fruit (5.00 cm) was found in germplasm No. 51 which was statistically similar with germplasm No. 52 (4.97 cm), No.80 (4.95cm), while the shortest fruit (2.55

cm) was measured from germplasm No.76 preceded by germplasm No. 65 (3.42 cm). The average length of fruit was found 4.37 cm per fruit. (Table 2)

Present findings were agreed with the findings of **Shirol *et al.* (2009); Brito and Narain(2002)** and they reported the length of sapota was about 4-6cm.and 5-6cm.

4.1.2.3 Width of fruit

Significant variation was found in respect of width of fruit among 30 germplasm. The broadest fruit (5.33 cm) was found in germplasm No.63 which was statistically similar to germplasm No. 78 (5.20 cm), No.54 (5.19cm), No. 51 (5.18cm) and the narrowest fruit (2.67 cm) was measured from germplasm No. 65, which was statistically similar to germplasm No. 76 (2.68 cm). The average width of fruit was found 4.39 cm per fruit. (Table 2)

The present result was in agreement with the findings of Verheij and Coronel (1992. They mentioned width of sapota was about 4 to 5cm.

4.1.2.4 Skin weight

The skin weight of the fruit was significantly varied among 30 germplasm. The germplasm No. 63 gave the maximum skin weight (14.36g) which was statistically similar to germplasm No. 70 (12.46g), while the skin weight was minimum in germplasm No.61 (2.38 g), which was statistically similar to germplasm No. 65 (2.41 g), No. 66 (3.65 g). Average skin weight of sapota was found 6.71 g. (Table 2)

4.1.2.5 Weight of stone

Significant difference was found among 30 germplasm in respect of weight of stone. The highest stone weight (3.65g) was obtained from germplasm No. 63 followed by the germplasm No.55 (2.53g), No.70(2.43g) while the lowest stone weight (1.07 g) was found in germplasm No.59, which was statistically similar with germplasm No. 60(1.08g), No. 64 (1.19g). Average seed weight was found 1.67 g per fruit. (Table 2)

4.1.2.6 Weight of non-edible portion

There was found significant variation among the 30 germplasm in relation to weight of non- edible portion. The maximum weight of non-edible portion (17.94g) was found in germplasm No. 63 followed by germplasm No. 70 (14.89g), and the minimum weight (3.53 g) was measured from germplasm No. 61 which was statistically similar to the germplasm No. 65 (3.70g), (Table 2). The average weight of non-edible portion of fruit was found 8.35 g. (Table 2)

4.1.2.7 Weight of edible portion

Significant difference was found among the 30 germplasm in respect of weight of edible portion of the sapota fruit. It is revealed from the result that the maximum weight of edible portion (84.89 g) was found in germplasm No. 80 which was statistically similar to germplasm No. 78 (78.69 g). The minimum weight (10.17 g) was measured from germplasm No. 65 which was statistically similar to the germplasm No. 61 (17.88 g), No. 66 (18.66 g). The average weight of edible portion of fruit was found 52.02 g. (Table 2)

4.1.2.8 Percentage of non-edible portion

The percentage of non-edible portion of sapota was significantly varied among the 30 germplasm. The highest percentage of non-edible portion was found from germplasm No. 65 (25.92 %) and No.64(25.20%) which was statistically similar to the germplasm No. 66(21.74%) and the lowest percentage (9.31 %) was found from germplasm No. 68 which was statistically similar to germplasm No 80(10.21 %), No 60(10.40 %), No. 54 (10.72 %), No. 71 (10.73 %), No. 72 (10.75 %), No. 57 (11.07 %), No.77 (11.31g). The average percentage of non-edible portion of sapota was found about 15.02 %. (Table 2)

4.1.2.9 Percentage of edible portion

Significant variation was found among the 30 germplasm in respect of percentage of edible portion of the fruit. The results showed that the highest percentage of edible portion (91.95 %) was found in germplasm No. 74 which was statistically similar to germplasm No. 68 (89.88 %), No. 80 (89.71%), No. 60 (89.60 %), No. 54 (89.28%), No.

72 (89.15 %), No. 71(89.04 %), No. 57 (88.93 %), No. 77 (88.48 %) and No. 76 (88.44 %), and the lowest percentage (70.79 %) was measured from germplasm No. 65 which was statistically similar to the germplasm No. 64 (74.98 %). The average percentage of edible portion of fruit was found 84. 95%. (Table 2)

4.1.3 Chemical characteristics of sapota

4.1.3.1 pH of fruit pulp

There was a significant variation among the 30 germplasm in respect of pH of fruit pulp. The highest pH of fruit pulp was found in germplasm No. 62 (6.54) which was statistically similar to germplasm No. 80 (5.75), No. 65(5.66). The lowest pH content of fruit pulp was found in germplasm No. 52 (4.05) preceded by germplasm No. 54 (4.26). Average pH content of fruit pulp was found 5.15. (Table 3)

Similar result in respect of pH of fruit pulp in the case of sapota was obtained by **Brito and Narendra (2002) and Kulkarni *et al.* (2006)**. They observed that pH of fruit pulp of sapota was about 4.9-5.5.and 5.36.

4.1.3.2 Total soluble solids (Brix %) of fruit pulp

The difference of total soluble solids was significant among the 30 germplasm. The highest percentage of TSS was observed from germplasm No. 54 (26.00 %) which was followed by the germplasm No. 70 (23.50 %), No. 59 (23.33%), No. 68 (22.00%).The lowest percentage of total soluble solids of fruit pulp was observed from germplasm No. 52 (12.97 %) which was statistically similar to germplasm No. 58 (13.67%), No. 53 (14.01 %). Average total soluble solids were found 18.57 % (Table 3) . Increase in total soluble solid may be attributed to increase in soluble sugar, soluble pectin, soluble organic acids etc.

Kulkarni *et al.* (2006) observed that TSS of fruit pulp of sapota was about 20.68.

Table 3. Chemical Characteristics of Sapota

SL No	GP No	PH	TSS (%)	T-acidity (%)	Vitamin C (mg/100g)	Carotenoids (mg/100gm)	Anthocyanin (mg/100gm)	Flavonoids (g/100g)
1	51	4.53q	17.00hijk	1.28ghi	4.96ijklm	0.05j	0.36e	10.19 defg
2	52	4.05t	12.97o	1.72 bc	3.73nop	0.21d	0.23i	9.15 hi
3	53	5.07k	14.01mno	1.69 bc	2.77q	0.09g	0.33f	9.49 gh
4	54	4.26s	26.00a	1.84 ab	4.40lmn	0.05j	0.24i	6.23jk
5	55	4.91m	14.90lmn	1.08kl	4.60klm	0.24c	0.59b	6.62j
6	56	4.84n	17.33ghij	1.50 de	4.17mnop	0.18e	1.28a	13.83b
7	57	4.45r	16.57ijkl	1.07kl	5.39hij	0.03j	0.46c	9.08hi
8	58	4.81o	13.67no	1.32fghi	5.40hij	0.08h	0.42d	14.27 b
9	59	5.26h	23.33b	1.75b	3.49pq	0.02k	0.17l	11.13 d
10	60	4.66p	19.90def	1.29fghi	3.57op	0.05j	0.28h	10.69 def
11	61	5.55d	16.97hijk	1.23 ijk	5.43hij	0.05j	0.36e	10.18defg
12	62	6.54a	15.43klm	1.08kl	6.55fg	0.21d	0.23i	9.14hi
13	63	5.26h	15.33klmn	1.39 efgh	7.79cd	0.09g	0.33f	9.48gh
14	64	5.47e	16.63ijkl	1.11jkl	2.82q	0.05j	0.24i	6.23jk
15	65	5.66c	15.83jkl	1.24 ij	3.69nop	0.24c	0.59b	6.62j
16	66	5.37g	15.97jkl	1.59 cd	3.41pq	0.18e	1.28a	13.81b
17	67	5.36g	21.23cd	1.36efghi	8.44bc	0.03j	0.46c	9.09hi
18	68	5.25h	22.00bc	1.10jkl	8.95b	0.08h	0.42d	14.2b
19	69	5.43f	20.43cde	1.04 l	7.10def	0.02k	0.17l	11.13 d
20	70	4.95l	23.50b	1.08kl	6.71efg	0.05j	0.28h	10.69def
21	71	5.56d	19.97def	1.32 fghi	5.65hi	0.06i	0.05o	10.82 de
22	72	5.55d	21.17cd	1.05l	4.34lmno	0.27b	0.28h	15.57a
23	73	5.17i	21.13cd	1.24hij	5.09 ijkl	0.04j	0.09m	12.35 c
24	74	5.07k	19.80def	1.91 a	6.69efg	0.08h	0.09m	8.38i
25	75	5.17i	20.33cde	1.08 kl	4.64jklm	0.19e	0.29g	5.14l
26	76	5.16i	20.27cde	1.07 kl	8.94b	0.41a	0.21j	9.87efgh
27	77	5.13j	18.40fgh	1.42 efg	7.37de	0.08h	0.18k	5.61kl
28	78	4.97l	18.03ghi	1.24ij	5.29hijk	0.13f	0.18k	6.78j
29	79	5.36g	19.00efg	1.44 ef	6.08gh	0.14f	0.11m	9.42gh
30	80	5.75b	19.90def	1.12 jkl	11.80a	0.04j	0.05 o	9.45fgh
	Average	5.15	18.57	1.32	5.64	0.115	0.34	9.83
	Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	C.V %	11.15	3.58	11.77	4.55	6.74	1.64	0.10

Note. In a column figures having similar letters do not differ significantly whereas figures having dissimilar letters differ significantly as per DMRT

4.1.3.3 Titratable acidity of fruit pulp

The titratable acidity showed significant variation among the 30 germplasm. The highest percentage of titratable acid content was found in germplasm No. 74 (1.91 %) which was statistically similar to the germplasm No. 54 (1.84 %) and No.59(1.75%). The lowest percentage of titratable acid content was recorded from germplasm No. 69 (1.04 %) which was statistically similar to germplasm No. 72 (1.05%), No. 57 (1.07 %), No.76(1.07%),No 55 (1.08%), No.75 (1.08%), No.70 (1.08%), No.62 (1.08%),. Average titratable acidity of fruit pulp was 1.32%.(Table 3)

Kulkarni *et al.* (2006) observed the similar result in case of titratable acidity of mature sapota at harvest period.

4.1.3.4 Vitamin C (ascorbic acid) content of fruit pulp

There was a significant variation among the 30 germplasm in respect of vitamin C content of fruit pulp. The highest vitamin C content of fruit pulp was found in germplasm No. 80 (11.80 mg /100 g) followed by germplasm No. 68 (8.95 mg /100 g), No. 76 (8.94 mg /100 g) and No. 67 (8.44 mg /100 g). The lowest amount of ascorbic acid content was observed from germplasm No. 53 (2.77 mg /100 g) which was statistically similar to germplasm No. 64 (2.82 mg /100 g). Average vitamin C content of fruit pulp was 5.64 mg /100 g. (Table 3)

Similar result in respect of vitamin C content was reported by **Nazarudeen (2008)**. They reported about vitamin C content of sapota was 6 mg per 100 g fruit pulp.

4.1.3.5 Carotenoids content of fruit pulp

Carotenoids content of fruit pulp showed significant difference among the 30 germplasm. The maximum amount of carotenoids content of fruit pulp was found in germplasm No. 76 (0.41 mg /100 g) followed by germplasm No. 72 (0.27 mg /100 g). The minimum amount of carotenoids content was observed a germplasm No. 57 (0.03 mg /100 g) which was statistically similar to that of germplasm. No.67 (0.03 mg/100 g). Average carotenoids content was 0.12 mg /100 g of fruit pulp. (Table 3)

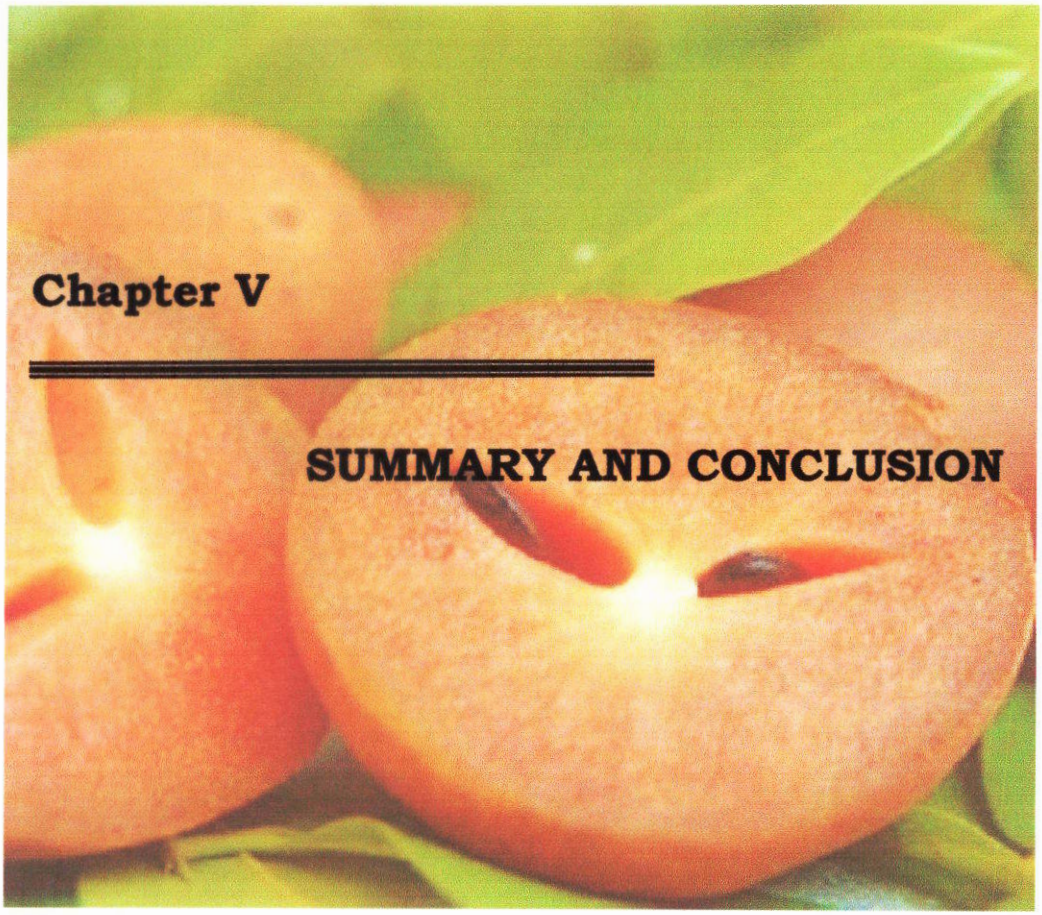
The present results were in agreement with the findings of **Alia *et al.* (2007).**

4.1.3.6 Anthocyanin content of fruit pulp

The difference of anthocyanin content of fruit pulp was significant among the 30 germplasm. The highest amount of anthocyanin of fruit pulp was observed from germplasm No. 66 (1.28 mg /100 g) which was followed by germplasm No.56 (1.27 mg /100 g). The least amount of anthocyanin of fruit pulp was observed from germplasm No 74(0.09 mg /100 g) which was statistically similar to germplasm No. 73 (0.09 mg /100 g). Average anthocyanin content of fruit pulp was 0.34 mg /100 g. (Table-3)

4.1.3.7 Flavonoids content of fruit pulp

The highest flavonoids content of fruit pulp was found in germplasm No. 72 (15.57 g /100g) followed by germplasm No. 58 (14.27 g / 100g),No.68(14.26g/100g),No. 56(13.83 g /100g) and No.66(13.81 g /100g).The lowest flavonoids content of fruit pulp was found in germplasm No. 75 (5.14g /100g) preceded by the germplasm No. 77 (5.61 g /100g) (Table 3). Average flavonoids content was 9.83 g /100 g of fruit pulp.(Table-3)



Chapter V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

A study on the physico-chemical characteristics of 30 germplasm of sapota was carried out during the period from February to July, 2011. The sapota germplasm was selected from South Western region of Bangladesh. Three fruits from each germplasm were collected for the study. The collected fruits were brought to the Horticulture Laboratory of the Agrotechnology Discipline of Khulna University, Khulna. In these fruits were kept in ambient temperature to determine their physico-chemical characteristics.

The experiment was laid out in Completely Randomized Design (CRD) with three replications. The collected data were recorded and analyzed for interpretation.

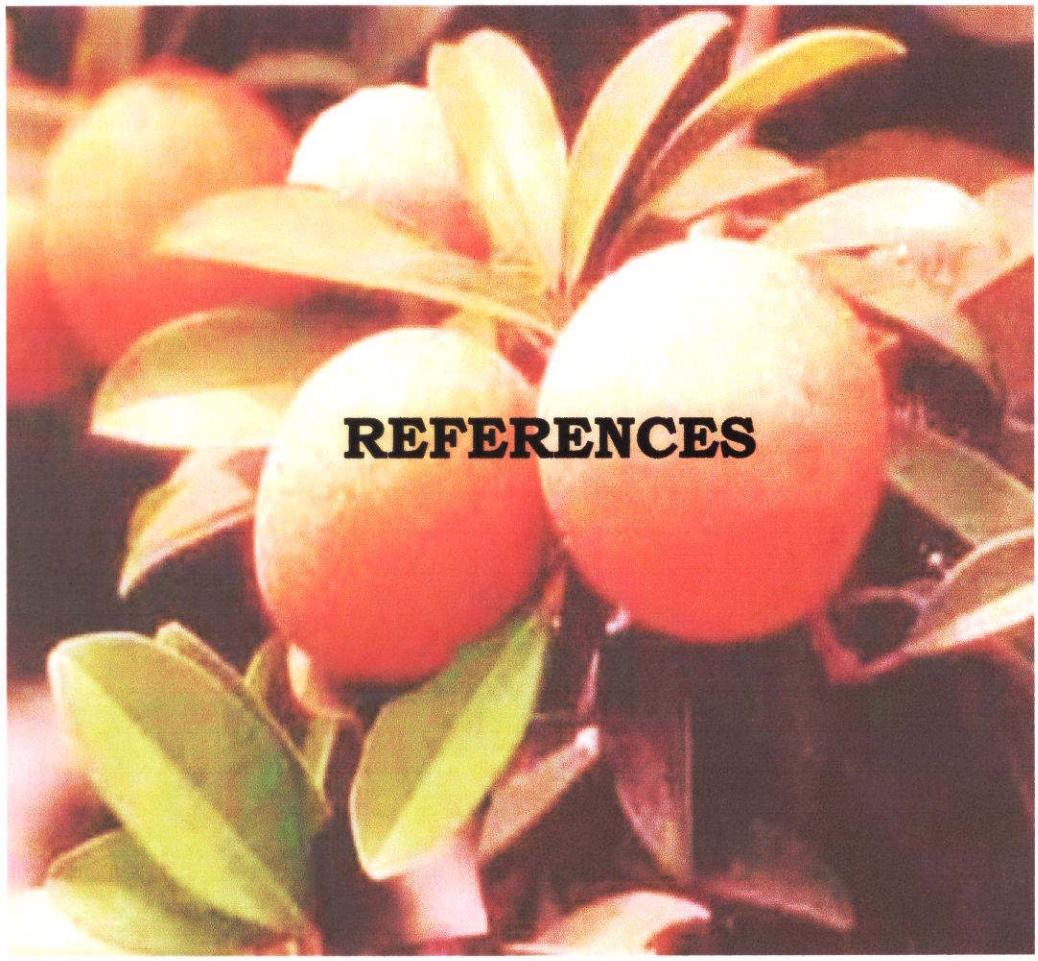
Weight of fruit, length of fruit, width of fruit, skin weight, stone weight, weight of edible and non-edible part were determined. Chemical characteristics of sapota such as pH, total soluble solid, T-acidity, vitamin C, carotenoids, anthocyanin, and flavonoids content of fruit pulp were determined.

Better performance was showed by germplasm No.80 in respect of total weight of fruit (94.39gm), highest amount of edible portion (84.89gm), the highest width (5.33cm) of fruits was observed in germplasm No. 63.The highest length (5cm) of fruit were determined from germplasm No. 51. The highest vitamin-C content (11.80mg/100g) among the 30 selected germplasm. The highest titrable acidity (1.91 %) content germplasm No 74 and while germplasm No. 62 was better in respect of pH (6.54)), germplasm No. 54 in total soluble solid (26.00 %) content, germplasm No. 76 in carotenoids (0.41mg /100 g) content, germplasm No. 66 in anthocyanin (1.28 mg /100 g) content and germplasm No. 72 in flavonoids (15.57 g /100g) content of fruit pulp. The overall observation indicates that sapota is rich in nutrients.

Maximum pH of fruit was found in germplasm No. 62 (6.54) and minimum in germplasm No. 52 (4.05); while average pH of fruit pulp was about 5.15. The highest percentage of TSS was observed in germplasm No. 54 (26.00 %) and lowest in germplasm No. 52 (12.97 %) and average observed percentage of TSS was 18.57 % per fruit. The highest percentage of T-acidity was found in germplasm No. 74 (1.91 %) and the lowest

percentage in germplasm No. 69 (1.04 %) and average percentage of T-acidity was recorded as 1.32%. The maximum vitamin C content of fruit pulp was recorded from germplasm No. 80 (11.80 mg /100 g) and the minimum from germplasm No. 53 (2.77 mg /100 g); while average vitamin C content of fruit pulp was 5.64 mg /100 g. The maximum carotenoids content of fruit pulp was found in germplasm No. 76 (0.41 mg /100 g) and the minimum was found in germplasm No. 57 (0.03 mg /100 g); while average carotenoids content was found 0.12 mg /100 g. The highest amount of anthocyanin of fruit pulp was observed from germplasm No. 66 (1.28 mg /100 g). The least amount of anthocyanin of fruit pulp was observed from germplasm No 74(0.09 mg /100 g), while average anthocyanin content was found 0.34 mg /100 g. The highest flavonoids content of fruit pulp was found in germplasm No. 72 (15.57 g /100g) and the lowest flavonoids content of fruit pulp was found in germplasm No. 75 (5.14g /100g), while average anthocyanin content was found 9.83 g /100 g of fruit pulp.

At the concluding point it can be said that the criteria for the selection of the sapota germplasm may be weight, length, width and percentage of edible portion of the fruit. Most of the characters were superior in germplasm No. 54, 62, 74, 76, and 80. More cultivation and commercialization of sapota could also be taken to augment total food supplies. This investigation can also serve as a basis for considering the sapota fruit as one of the health fruits of the millennium. Consumption of sapota is recommended in herbal medicine as it is also thought to have innumerable medicinal uses. By developing several products from sapota, it is possible to reduce post harvest losses of this fruit and there are enormous scopes of industrial product development. If the cultivation and formulation of products from sapota increases not only it will help to reduce malnutrition problem and if we can know the fruit value of sapota then it will also help to improve the economic condition of the farmers of Bangladesh.


REFERENCES

References

Adhaoo, 1976. Engineering properties of groundnut and jowar, Part – I physical properties.J. Agri. Eng. 13(1): 19-21.

Alia, T.; R. Villanueva, C. Pelayo; M.T. Colinas, V. Lopez and S. Bautista. 2007. Postharvest physiology and technology of sapote mamey fruit (*Pouteria sapota* (Jacq.). Facultad de Ciencias Agropecuarias, Universidad Autónoma del Estado de Morelos, Av.Universidad 1001, Cuernavaca, Morelos, Mexico, 45 (3): 285-297.

Ali, S. M. ; S.C. Mandhar, A. Ganachari. U. Nidoni and M. Ananthacharya . 2010. Design and development of electronic weight grader for sapota (*Manilkara achras (Mill). fosberg*). Int. J. Eng. Sci.Tech. 2(12): 7555- 7561.

Alink, G. M. and J.H. Koeman . 2002. The pro-oxidant chemistry of the natural antioxidants vitamin C, vitamin E, carotenoids and flavonoids. Environ. Toxicol. Pharmacol, 11: 321–333.

AOAC. 1990. *Official Methods of Analysis*, 15th Ed., Assoc. of Official Analytical Chemists, Arlington, 39: 583–588.. 1990.

Aruoma, O. I. 1994. Nutrition and health aspects of free radicals and antioxidants. Food Chem. Toxicol, 32: 671–683.

Baker, R. A.; N. Berry and Y.H. Hup, 1996. Fruit preserves and jams in processing fruits— Science and Technology, Vol 1. Biology, Principles and Application. Technomic Publishing Co., Inc. Switzerland, pp. 117– 133.

Balerdi, C. F. and P. E. Shaw, 1998 Sapodilla, sapote and related fruit. Tropical and subtropical fruits. Auburndale: AgScience, pp. 78-136.

Brito, S. E and N. Narain, 2002. Physical and chemical characteristics of sapota fruit at different stages of maturation. Universidade Federal da Paraíba, Dep. de Tecnologia Química e de Alimentos, 37(4):567-572.

Broughton, W. J and H. C. Wong . 1979. Storage conditions and ripening of chiku fruits *Achras sapota* L. Scientia Horticulturae, Amsterdam, 10(4): 377-385 .

Byers, T. and G. Perry, 1992. Dietary carotenes, vitamin C and vitamin E as protective antioxidants in human cancers. Annu. Rev. Nutr, 12: 139–159.

Chaughulea, R. S., P. C. Malib, R.S. Patilb, G.D. Joshib and Y.M. Lo.2002. Magnetic resonance spectroscopy study of sapota fruits at various growth stages. Innov. Food Sci. Emerging Technol. 3: 185-190.

Craig, W.J. 1997. Phytochemicals: Guardians of our health. J.American Diet, 97:199–204.

Doublier, J and J.Thibault .1984. Les agents epaississants de fabrication dans les industries agroalimentories. In: Tec et Doc. Multon, J.C. (ed.) Apria, Lavoisier. Paris, p. 305.

Franke, A. A.; L. J. Custer, C. Arakaki and S.P. Murphy. 2004. Vitamin C and flavonoid levels of fruits and vegetables consumed in Hawaii. J. Food Comp. Anal, 17:1–35.

Fraser, G. E. 1999. Diet as primordial prevention in Seventh-Day Adventists. Prev. Med, 29(6):18–23.

Frei, B.; L. England and B.N. Ames.1989. Ascorbate is an outstanding antioxidant in human blood serum. Proc. Natl. Acad. Science USA, 86: 6377–6381.

Garcia-Alonso, M., S. Pascual-Teresa., C. Santos-Buelga, and J.C. Rivas-Gonzalo. 2004. Evaluation of the antioxidant properties of fruits. Food Chem, 84: 13–18.

Hallwell, B.; J.M.C. Gutteridge and C.E. Cross 1992. Free radicals, antioxidants and human disease: Where are we now? J. Lab. Clin. Med, 119:598–620.

Heim, K.E.; A.R. Tagliaferro and D.J. Bobilya. 2002. Flavonoid antioxidants: Chemistry and structure-activity relationships. J. Nutr. Biochem, 13: 572–584.

Kellcy, E. B. and S. Nitzke.1995. Early adolescents' perceptions of the role of dietary fat in heart disease, cancer and obesity. J. American Diet Assoc. 95(9): 412

Kulkarni, A. P.; S. A. Policegoudra and S.M. Aradhya.2006.Chemical composition and Antioxidant activity of sapota (*Achras Sapota linn.)*fruit. J.of Food Biochem. 31: 399–414.

Kulkarni,A. P.; S. A. Policegoudra and S.M. Aradhya .2004. Isolation and identification of a radical scavenging antioxidant – punicalagin from pith and carpellary membrane of pomegranate fruit. Food Chemistry, 87: 551–557.

Kuti, J. O. 2004. Antioxidant compounds from four *Opuntia cactus* pear fruit varieties. Food Chemistry, 85: 527–533.

Kwong, W. T., P.Friello and R. D. Semba, 2004. Interactions between iron deficiency and lead poisoning: Epidemiology and pathogenesis.Science Total Environment, 330:21–37.

Lakshminarayana, S.and M. A. M.Rivera. 1979. Proximate characteristics and composition of sapodila fruits grown in Mexico. Proceedings of the Florida State Horticultural Society, Goldenrod, 20:303-305.

Lynch, S.R. 2005. The impact of iron fortification on nutritional anemia.Best Pract. Res. Clin. Haematol, 18(2): 333–346.

Mathew, A. G. and S. Lakshminaraynna . 1969. Polyphenols of immature sapota fruit. Phytochemistry, 8: 507–509.

Mccarty, M. F. 2004. Proposal for a dietary "phytochemical index." Med. Hypotheses, 63: 813–817.

Mandhar, S. C and G. Senthilkumaran. 1995. Devolopment of sapota grader. Proceedings of national seminar on post harvest technology of fruit.Phalasamskarana-95 held at Bangalore, 3: 323-327.

Mark M., C. H. Michael & C. Cleveland. 2010.. *Petenes mangroves*. Encyclopedia of Earth. National Council for Science and the Environment. Washington DC, 11: 271–290.

Mazumdar and Majumdar (2001) and Saini *et al.* (2006): Handbook of analysis and quality control for sapota fruits, Junagadh Agril. University, Gujrat, 3:123-125.

Mohensin, 1996.Physical properties of plant and animal materials vol I-structure physical charecteristics and mechanical properties-Gordon and beach publishers, New York.734 ISSN: 0975-5462 7560.

Moore, H. E and Steam 2009. Pouteria sapota. Agroforestry Database, 5: 103-112.

Morton, J. and F. L. Miami, 1987. Sapote. In: Fruits of warm climates, 2: 398–402.

Moura, R. J. M.; J. E. F. Bezerra, M. A. Silva, and A. T. Cavalcante. 1983. Comportamento de matrizes de sapotizeiro. Revista Brasileira de Fruticultura, Cruz das Almas, 5: 103- 112.

Nazarudeen (2008). Chemistry and structure-activity relationships. J. Nutr. Biochem, 13: 572–584.

Orwa C., A. Mutua , R. Kindt , R. Jamnadas and A. Simons. 2009. Agroforestree Database:a tree reference and selection guide version 4.0.

Ranganna, S.1986. Handbook of analysis and quality control for fruits and vegetable products, New delhi, Tata-Mcgraw, pp. 1-181.

Rangamna, S. 2001. Proximate constituents. In Handbook of Analysis and Quality Control for Fruit and Vegetable Products, 2nd Ed., (S. Ranganna, ed.) Tata McGraw-Hill, New Delhi, India, pp. 12-17.

Royen 2010. Manilkara zapota (L.) P *Germplasm Resources Information Network*. United States Department of Agriculture, 52: 7834–7841.

Rice-evans, C.A.; N.J. Miller, and G. Paganga, 1996. Structure antioxidant activity relationships of flavonoids and phenolic acids. Free Radical Biol. Med, 20: 933–956.

Selvaraj, Y. and D.K. Pal. 1984. Changes in the chemical composition and enzyme activity of the two-sapodilla cultivars during development and ripening. Journal of Horticulture. Science, 59: 275–281.

Shanmugavelu, K.G. and G. Srinivasan. 1973. Proximate composition of fruits of sapota cultivars. South Ind Hort, 21: 107–108.

Siddappa, G.S. and B.S. Bhatia. 1954. The identification of sugar in fruit by paper chromatography. Indian Journal of Horticulture, 11: 19–23.

Shirol. A. M .,V. C. Kanamadi, S. Patil and N. Thammaiah.2009. Studies on the performance of new sapota cultivars under Ghataprabha command area. AICRP (Tropical Fruits), KRC College of Horticulture,Belgavi, Karnataka, India, 22 (5): 1056-1057.

Shui, G., S.P. Wong and L.P Leong . 2004. Characterization of antioxidants and change of antioxidant levels during storage of *Manilkara zapota* L. J. Agric. Food Chem, 52:7834–7841.

Vahora, A.M., Y.N. Tandel and C.B. Patel. 2009. Effect of different season and varieties on physical properties of sapota. The Asian Journal of Horticulture, 4 (2): 440-442.

Verheij, E.W.M. and Coronel, R.E. 1992. Edible fruits and nuts; Plant Resources of South- East Asia. PROSEA, Bogor, Indonesia, pp. 190-191.

Vyas, D.M. and R.V. Shah, 2004. Design and development of on farm sapota grader. Abstracts, M.Tech. thesis and B.Tech. dissertions of Agril. Process and food engg. Dept. of Agril. Process Engg., Junagadh Agril. University, Gujrat, 4:123-127.

Yahia, E. M., F.Orozco and C.A.Leon, 2010. Phytochemical and antioxidant characterization of mamey (*Pouteria sapota* Jacq. H.E. Moore & Stearn) fruit *Journal of Food Biochemistry,* 31(3): 399–414.

Zhang, D. and Y. Hamauzu. 2004. Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. Food Chem. 88: 503–509.

APPENDIX-IX

List of sapota germplasm with English name, local name, scientific name and area of collection.

Germplasm No.	English Name	Local Name	Scientific name	Area of collection
51	Sapota	Deshi sofeda	*Achras sapota*	Satkhira
52	Sapota	Gobeda	*Achras sapota*	Satkhira
53	Sapota	Deshi sofeda	*Achras sapota*	Satkhira
54	Sapota	Deshi sofeda	*Achras sapota*	Satkhira
55	Sapota	Gobeda majhari	*Achras sapota*	Satkhira
56	Sapota	Deshi sofeda	*Achras sapota*	Satkhira
57	Sapota	Bokul sofeda	*Achras sapota*	Satkhira
58	Sapota	Boro sofeda	*Achras sapota*	Satkhira
59	Sapota	Narkele sofeda	*Achras sapota*	Satkhira
60	Sapota	Boro sofeda	*Achras sapota*	Satkhira
61	Sapota	Boro sofeda	*Achras sapota*	Satkhira
62	Sapota	Gobeda majhari	*Achras sapota*	Satkhira
63	Sapota	Gobeda boro	*Achras sapota*	Satkhira
64	Sapota	Gobeda majhari	*Achras sapota*	Satkhira
65	Sapota	Deshi sofeda	*Achras sapota*	Satkhira
66	Sapota	Boro sofeda	*Achras sapota*	Satkhira
67	Sapota	Narkele sofeda	*Achras sapota*	Satkhira
68	Sapota	Boro sofeda	*Achras sapota*	Satkhira
69	Sapota	Gobeda majhari	*Achras sapota*	Satkhira
70	Sapota	Gobeda boro	*Achras sapota*	Satkhira