PHYSICO-CHEMICAL CHARACTERISTICS OF SOME INDIGENOUS CULTIVARS OF MANGO

A THESIS

BY

SULTANA MAHMUDA

Registration No. 1605340

Session: 2016-2017

Thesis Semester: January-June, 2018

MASTER OF SCIENCE (M.S.)

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HORTICULTURE

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DEPARTMENT OF HORTICULTURE
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DEDICATED
TO MY
BELOVED PARENTS

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The Authoress

ABSTRACT

The lab-based experiment was carried out in the laboratory of Horticulture and the laboratory of Food Precessing and Preservation, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during June, 2017 to July 2017 to determine the physico-chemical characteristics of some indigenous cultivars of mango. This single factor experiment was conducted in Completely Randomized Design (CRD) with five replications. The fruits of 13 indigenous cultivars of mango chosen from the well-managed orchard in Teroroshia, upazila Shibganj under Chapai Nawabganj district were: Monmohan, Kheermohan, Golapbaas, Lakhno, Haaji, Sonamohan, Kalibhog, Madhuchuski, Bhaaduria, Koitori, Kuapahari, Phunia and Belbhog. In this assessment of physical and biochemical attributes, all of those were significant ($p \leq 0.05$). Regarding the physical parameters, the longest fruit (133.79 cm), maximum pericarp (87.90 g) and weight of stone (62.33 g) were in Bhaaduria and the shortest fruit (84.57 cm), lowest diameter (54.73 cm), lowest fruit (157.5 g), pericarp (38.93 g), stone (30.17 g) and pulp weight (88.40 g), lower pulp and stone ratio (2.94), lowest firmness (1.53 kg/cm^2) was in Golapbaas. Regarding the yield contributing character, the highest fruit weight (385.03 g) was in Kheermohan and the least was in Golapbaas. However,the highest pulp and stone ratio was in Lakhno (5.81) while the maximum firmness value was detected in Kalibhog (3.40 kg/cm^2). After detecting colours, the pericarp of Monmohan, Lakhno, Haaji, Sonamohan and Koitori were yellow in colour, while Kheermohan, Golapbaas, Kalibhog, Madhuchuski, Bhaaduria and Kuapahari were greenish in colour, respectively. The pulp of Kheermohan and Kuapahari were red in colour and Sonamohan, Koitori and Madhuchuski were yellowish in colour, respectively. The present study also showed that Madhuchuski had the highest shelf-life (10.67 days) compared to other cultivars and Bhaaduria had lowest shelf-life (6.33 days). Considering the biochemical properties, Bhaaduria had the highest TSS (27.33 %), maximum polyphenol contents (104.46 mg GAE/100 g fw) and lowest non-reducing sugar (13.25 mg/100 g fw) while Golapbaas had the lowest TSS (13.0%), lowest vitamin C content (27.90 mg/100 g fw), minimum polyphenol contents (74.46 mg GAE/100 g fw) and highest reducing sugar content (18.09 mg/100 g fw). The highest amount of vitamin C was detected in Kuapahari (65.97 mg/100 g fw). Furthermore, the highest concentration of β-carotene was detected in Madhuchuski (7.14 mg/100 g fw) and the lowest one in Haaji (3.37 mg/100 g fw). The highest amount of non-reducing sugar was recorded in Monmohan (25.34 mg/100 g fw) but Monmohan had lowest reducing sugar (5.41 mg/100 g fw). In respect of pulp pH, the highest pH value was found in Kuapahari (6.41) while the lowest value was in Sonamohan (5.29). Considering the overall physical and biochemical characteristics, Bhaaduria, Kheermohan and Madhuchuski were found to be promising for fresh consumption, processing industry and varietal development programme.

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LIST OF SYMBOLS AND ABBREVIATIONS

°C	Degree Centigrade
ANOVA	Analysis of Variance
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
Contd.	Continued
CRD	Complete Randomized Design
Cult.	Culture
cv.	Cultivar
Dept.	Department
DNS	3, 5-di-nitro salicylic acid
et al.	And others
FAO	Food and Agriculture Organization
fw	Fresh weight
g	Gram
GAE	Gallic Acid Equivalents
HSTU	Hajee Mohammad Danesh Science and Technology University
i.e.	That is
kg	Kilogram
Lsd	Least Significant Difference
mg	Milligram
TSS	Total Soluble Solids
UK	United Kingdom
UV-VIS	Ultraviolet and Visible
var.	Variety
viz.	Namely
nm	Nanometer

CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

Mango (*Mangifera indica* L.), commonly known as the 'King of fruits' belongs to the family Anacardiaceae. It is the choicest fruit of the country and because of its great utility, characteristic pleasant aroma and excellent flavour. It is native to South Asia from where the 'common mango' or *Mangifera indica* has been distributed worldwide to become one of the most widely cultivated fruits in the tropics. In Bangladesh, in terms of total area and production of fruit crops, mango ranks first in area and third in production (BBS, 2016). The ripe fruit varies in size and colour, and carry a single, flat, oblong pit that can be fibrous or hairy on the surface and which does not separate easily from the pulp. The fruits can be consumed in both fresh ripe and processed forms. It can also be eaten as juice, pickles, jams, jelly, candy, sauces etc. purposes. Mango can play an important role in balancing human diet by providing about 64-86 calories of energy per 100 g (Rathore *et al.*, 2007) and, when consumed regularly, can be a valuable dietary source of many phytochemical compounds (Haard and Chism, 1996). A fully ripe mango is especially high in vitamin A, which is considered a cancer-fighting agent. It is also high in vitamin C and is a good source of polyphenols, β-carotene and fibre too. Each part of the mango has medicinal uses. Its food value is greatly dependent on its chemical composition, such as dry matter, titrable acidity, total sugar, total soluble solid and ascorbic acid which facilitates development of postharvest quality, intrinsic quality such as flavour and taste, transportability and processing.

The mango grows in almost all parts of Bangladesh but the commercial and good quality grafted mangoes with known varietals identify are mostly grown in North-Western districts namely, Chapai Nawabganj, Rajshahi, Dinajpur and Rangpur with small production in Kushtia (Bhuyan, 1995). Out of the total production of commercial mango, nearly 70% is grown in greater Rajshahi alone, and the rest is grown in Dinajpur, Rangpur and Kushtia (Karim, 1985). The commercial cultivars namely, Langra, Gopalbhog, Khirshapat, Fazlee, Ashwina and Lakhno grown in these regions are not enough to meet the increasing demand of the large growing population of country. Besides these, fruit growers of Bangladesh, are also cultivating a number of unknown mango cultivars (Gooti mangoes) locally for higher production, breeding purposes due to their good quality. But the characteristics of most of these indigenous cultivars have not

yet been studied systematically. Presently, about 148 mango cultivars are being cultivated in the Chapai Nawabganj district (Shirin, 2013). Out of those, 11 are commercial cultivars and 37 are local cultivars which seem to have commercial importance.

Assessment of physical and biochemical properties of these cultivars is important for fresh market, export market and processing industries. About 35 to 38% post-harvest losses of mangoes have been reported during its ripening, transportation, storage and marketing (Rubbi *et al.*, 1985) mainly owing to selection of faulty cultivars, which have short shelf-life. Shelf-life as well as biochemical properties are also important for export in the international market whether in fresh or processed forms. However, the information regarding the complete profile of some common cultivars of mango have been well-documented in our country. Ara *et al.* (2014) evaluated the nutritional properties of some common cultivars (Amrapali, Chausa, Fazlee, Gopalbhog, Gooti, Himsagor, Khirshapat, Kohitoor, Langra and Mallika). While Islam *et al.* (2013) studied some biochemical properties such as TSS, titrable acidity, sugar contents, pulp pH along with shelf-life of some treated other mango cultivars. Some other authors also worked on the changes in the physico-chemical composition of common mango cultivars in Bangladesh at different stages of maturity and ripening (Shahjahan *et al.*, 1994 and Absar *et al.*, 1993). But to the best of our knowledge, in Bangladesh, there is no accessible published information regarding the complete profile of physico-chemical properties of indigenous cultivars of mango. This constitutes a major research gap since the high nutrient content should be given to priority in selection of mango cultivar for consumption and its further expansion for cultivation. Furthermore, the growers can get the inspiration of producing much more indigenous cultivars of mangoes throughout the country. This will add to their income through growing, processing and create additional employment opportunities for the rural people. Therefore, the present study was taken with the following objectives:

- to assess the physical characteristics of some indigenous cultivars of mango in Bangladesh
- to evaluate the biochemical properties of those indigenous cultivars of mango in Bangladesh

CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Mango is an important and popular fruit of Bangladesh. It has a unique position due to its nutritional quality, taste, consumer's preference etc. Mango is now recognized as one of the choicest fruits in the world market for its excellent flavour, attractive colour and delicious taste. Some of the most relevant works on physico-chemical properties of mango have been reviewed in this chapter.

2.1 The mango (*Mangifera indica* L.)

Mango is a member of the family Anacardiaceae. The genus *Mangifera* includes 25 species (Mabberly, 1997) with edible fruits such as *Mangifera caesia, M. foetida, M. odorata* and *M. pajang,* although *M. indica,* the mango, is the only species that is grown commercially on a large scale.

There are two races of mango; one from India and the other from Southeast Asia. The Indian race is intolerant to humidity, has flushes of bright red new growth that is subject to powdery mildew and anthracnose and bears mono-embryonic fruit of high colour and regular shape (Matsuoka, 2000). The Southeast Asian race is tolerant to excess moisture, has pale green or red new growth and resists powdery mildew. Its polyembryonic fruit is pale green and has an elongated kidney shape (Karihaloo *et al.*, 2003).

The tree is a deep-rooted, evergreen plant which can develop into huge trees, especially on deep soils. The height and shape varies considerably among seedlings and cultivars. Under optimum climatic conditions, the trees are erect and fast growing and the canopy can either be broad and rounded or more upright. Seedling trees can reach more than 20 m in height while grafted ones are usually half that size (Iyer *et al.*, 2009).

The tree is long-lived with some specimens known to be over 150 years old and still producing fruits. The mature leaves are simple, entire, leathery, dark green and glossy; they are usually pale green or red while young. They are short-pointed, oblong and lanceolate in shape and relatively long and narrow, often measuring more than 30 cm in length and up to 13 cm in width (Salim *et al.*, 2002). New leaves are formed in periodic flushes about two to three times a year. In deep soil the taproot descends to a depth of 20 ft, and the profuse, wide-spreading feeder roots also send down many anchor roots which penetrate for several feet (Matsuoka, 2000).

The fruits can be oval, egg shaped and round depending on the variety with smooth and soft skin. When ripe, the skin is usually a combination of green, red, and yellow depending on the variety (Matsuoka, 2000). The interior flesh is bright orange and soft with a large, flat pit in the middle in all ripe varieties. The fruit has a rich luscious, aromatic flavour and a taste in which sweetness and acidity are pleasantly blended. It contains a high concentration of sugar (16–18% w/v) and many acids with organoleptic properties, and also antioxidants like carotene (Hobson *et al.*, 1993). Sucrose, glucose and fructose are the principal sugars in ripened mango. Small amounts of cellulose, hemicellulose and pectin are also present (Reddy, 2005).

Mango fruit matures in 100 to 150 days after flowering (Knight, 1997). The fruit will have the best flavour if allowed to ripen on the tree. Ripening fruit turns the characteristic colour of the variety and begins to soften to the touch, much like a peach (Knight, 1997). Commercial marketability requires 13% dissolved solids (sugars). The fruit ripens best if placed stem end down in trays to prevent the sap from spreading to other parts of the fruit and also to encourage even ripening at room temperature (20-25°C) and covered with a dampened cloth to avoid shriveling (Griesbach., 1992).

2.2 Origin, production, composition and nutritive value

Mango is originated in India, Myanmar, Malaya or Thiland (Salunkhe and Desai, 1984). Now it is a commercial fruit in many countries of the world. The chief mango producing countries of the world are India, Pakistan, Mexico, Brazil, Haiti and Philippines. Mango is also grown in Indonesia, Java, Thailand, Srilanka, and Northwest Australia, India being the largest producer (Salunkhe and Desai, 1984).

Mango is grown in almost all parts of Bangladesh. But the commercial and good quality grafted mangoes with known varietal identity are mostly confined in a few districts namely, Chapai Nawabganj, Rajshahi, Dinajpur and Rangpur with small production in Kushtia. Of the total production of commercial mango, nearly 70% is grown in greater Rajshahi alone, and the rest is grown in Dinajpur, Rangpur and Kushtia (Karim, 1985).

In Bangladesh, mango ranks first in terms of area and third in production. Among the fruits mango occupies an area of about 50470 hectares. The present production of mango is around 187220 metric tones, which comes to about 3.71 metric tones per hectare (BBS, 2003).

Ahmed (1982) reported that mangoes are one of the richest sources of vitamin A. They contain a good amount of Niacin and Riboflavin and a fair quantity of vitamin C. Unripe mangoes are rich source of vitamin C and Iron.

Jain (1961) has reviewed the chemical composition of mango. It is a rich source of carbohydrate as well as vitamin A and C. The following are the average ranges of nutrients present in mango (25 varieties).

Chemical constituents	Quantity
Moisture	73.9 - 86.7 %
Carbohydrate	11.6 - 24.3
Protein	03- 1.0%
Fat	0.1 - 0.8
Minerals	0.3 0.7
Vitamin A	650 - 24,940 I.U.
Vitamin C	3.0 - 83.0 mg/100 gm

Sugar constitutes the main bulk of the carbohydrates and most of the soluble solids in the ripe mango.

The mango can be separated into three parts - skin, flesh or pulp and stone. Philippine mangoes have been found to contain 11 to 18% skin, 14 to 22% seed and 60 to 73% pulp (Pratt and Del Rosario, 1913), whereas mangoes in Hawaii contain an average of 63 to 77% of edible matter (Pope, 1929). The flesh content of mango, as reported from various mango-growing zones, varies from 58 to 75% (Winton and Winton, 1935). From the result of analysis of twenty-one varieties of mangoes growing in Florida, it appears that the seed varies from 6.8 to 17.9%, the skin 9.3 to 16.5% and the pulp 69.1 to 93.3% (Mustard and Lynch, 1945).

Ali and Mazher (1960) studied the various characteristics and chemical composition of mango and reported that the fruit contain water from 76 to 86% according to variety.

Nutritionally, mango is highly important because it has medium calorific and high nutritional values. Carbohydrate content in ripe mango pulp is 16.9% (Salunkhe and Desai. 1984). It is also a rich source of vitamins, minerals and total soluble solid (TSS) and therefore, prevent many deficiency diseases (Samad *et al.*, 1975; Purohit, 1985).

Samad *et al.* (1975) studied the fruits of ten varieties of mango. The moisture percentage was the highest (87.55%) in Ranibhog whereas it was the lowest (78.96%) in Misribhog. This trait for the different varieties under consideration ranged from 78.96 to 87.55%.

Palaniswamy *et al.* (1974) found maximum acidity in cv. Neelum and minimum in cv. Baueshan and K-0.8. Adsule and Roy (1974) reported that the tritable acidity varied from 0.14 to 0.46% among the north Indian varieties. The maximum acidity in cv. Khud pasand (0.409%) and minimum in cv. Jhumka (0.16%) while other mango varieties of Mursidabad showed variation in acidity in the range of 0.161 to 0.275% (Sadhu and Bose, 1976). Ghosh *et al.* (1985) reported maximum acidity of 0.32% in mango varieties Amriti, Meghlathana and Bombay Yellow and minimum in cv. Saradamonibhog. Sanyal *et al.* (1991) described maximum acidity of 0.38% in mango cv. Krishanbhog and less acidity in cv. Samar Bahist Chausa, Zardalu and Bangalora.

Gafur *et al.* (1994) investigated the concentration of vitamin C contents with varieties Ashwina, Fazli and Langra. They reported the highest concentration of vitamin C in fruit juice after fruit set. The concentration of ascorbic acid decreased with fruit development. They further reported that after 12 weeks of fruits set, cv. Langra contained the highest quantity of ascorbic acid (105 mg/100g), followed by Ashwina and Fazli (65.7 and 17.3 mg/100g, respectively). They also reported that ascorbic acid decreased with increase of storage duration. Absar *et al.* (1993) and Shahjahan *et al.* (1994) studied the major varieties of Bangladesh and found a gradual decreasing tendency of vitamin C towards maturity. In another study Joshi and Roy (1988) observed a continuous decrease of vitamin C during ripening, transportation and storage (10°C for up to 32 days).

In an experiment with twelve mango varieties Mollah and Siddique (1973) noted the highest ash content in the pulp of Khirsapat (1.04%) and the lowest in Fazli (0.49%).

Malek *et al.* (1966) reported that vitamin C of edible ripe fruits of different mango varieties is in the range of 3.43 to 62.96 mg per 100 g of pulp. Singh (1968) also reported that tendency of decreasing vitamin C content of mature fruit, during ripening was less than that of immature ones.

Srivastava (1967) narrated that ash content of mango fruits ranged from 0.26 to 1.66 percent. On the other hand, Singh (1968) observed that ash content of mango fruits depend on varieties and he showed that it was 0.26 to 1.16 percent.

Singh (1968) found significant changes in the amount of non-reducing sugars. The non-reducing sugar content remained more or less constant, after attaining peak. It was increased rapidly during the first 4-5 days of storage and then leveled off as reported by Joshi and Roy (1988). Rangavalli *et al.* (1993) studied the post-harvest changes in mango and found a gradual increase in non- reducing sugar content.

Singh (1968) reported that total sugar content of mango varied from 11.5 to 25%. While working with mango fruits cv. 'Gaurjeet'. Upadhyay and Tripathi (1985) reported that total sugar content was increased gradually, when stored for 6 days at room temperature (32-35°C). In case of 'Mallika' the total sugar content decreased initially until maturity, where as total sugars increased throughout the growing period in 'Langra' as described by Tandon *et al.* (1985). Joshi and Roy (1988) reported that during transport and storage, a rise followed by decline was observed in total sugars. Sugars contents increased during ripening (Srivastava, 1967).

Srivastava (1967) reported that mango contained an appreciable amount of vitamin C when it was green and tender with a value as high as 34.85 mg per 100 g of mango pulp in ripe fruit it was much lower. Ascorbic acid generally decreased during ripening. As the fruit became over-ripe the percentage of ascorbic decreased progressively. Vitamin C of edible ripe fruits of different mango varieties was reported to be in the range of 3.43 to 62.96 mg per 100 g of pulp (Iguina de George *et al.*, 1969 and Malek *et al.*, 1966). They also reported that the tendency of decrease in vitamin C content of mature fruit during repining was less than that of immature.

The green fruits stored at 10-12°C temperature for 7 weeks showed little change in vitamin C content. Maximum portion of vitamin C was lost when the fruits were stored at room temperature (26-30°C). In addition reduction in vitamin C with progress of fruit maturity and ripening was found in cv. Gopalbhog, Khirshapat, Langra and Fazli as decreased by Shahjahan *et al.* (1994). Laborem *et al.* (1992) reported that there was a tendency for ascorbic acid to be higher in cold storage.

Srivastava (1967) conducted an experiment with 22 mango cultivars collected from various parts of India and chemical analysis was performed. He reported that acid content (expressed as malic acid) ranged from 0.67 to 3.66% in green mango and 0.18 to 0.56% in ripe mango fruits. Shahajan *et al.* (1994) revealed that acidity of mango was

decreased gradually at the time of storage and ripening. They also found that percent acidity in green and ripe mango cv. Fazli was 0.32 and 0.10 respectively.

According to Upadhyay and Tripathi (1985) and Hossain *et al.* (1999) titratable acidity was decreased during storage and ripening. Leon and Lima (1968) and Medlicott *et al.*, (1990) also observed similar results. They found that acidity was reduced during later stage of growth on attainment of maturity and ripening. Dhalla and Hanson (1988) reported that post-harvest treatments for the extension of storage life delayed in decrease of titratable acid content. Lam and Wong (1988) stated that there were no differences in titratable acid content when 'Aarumanis' mango was stored in cold storage of different storage temperatures. Joshi and Roy (1988) reported continuous decrease in titratable acid content during storage.

Observational data indicated that fully mature fruits stored for up to 6 days at room temperature, percentage contents reducing sugars were highest on the 6th day (Tripathi, 1988) and reducing sugars increased gradually with fruit ripening (Upadhyay and Tripathi, 1985). In another experiment Tandon *et al.* (1985) reported that reducing sugars increased until harvest. Similarly, Castro *et al.* (1992) also observed that reducing sugar was increased slightly during ripening. Rangavalli *et al.* (1993) found that reducing sugar content was gradually increased among reached the highest peak of 7.5 percent.

Lianni *et al.* (1994) showed that total soluble solids content of mango was increased markedly up to 5 days after harvest.

2.3 Physical characteristics of harvested mangoes

Souza *et al.* (2018) conducted an experiment at the São Manuel Experimental Farm, School of Agriculture, Botucatu, São Paulo State University (UNESP), Brazil, Espada Vermelha to evaluate the physicochemical characteristics and bioactive compounds of mango fruits named Keitt and Palmer cultivars under subtropical conditions. For physical analysis, weight, longitudinal and transverse diameters, fruit shape, pulp yield, peel, seed, peel colour and pulp colour were evaluated. The results showed that Palmer and Keitt cultivars had higher physical quality, such as higher pulp yield, analyzed under subtropical conditions of Brazil.

Rasha *et al.* (2016) carried out an experiment where selected physical quality attributes of three mango cultivars Kitchener, Abusamaka and Tommy Atkins collected from

central Sudan, were evaluated at ripening stage during two successive seasons (2013 and 2014). The experiments were arranged in Complete Randomize Design (CRD) with three replications. Results showed that cultivars had significant differences in fruit weight, fruit length, fruit width, pulp weight, pulp thickness, seed weight, seed length, seed width and peel weight in the two seasons. The present study revealed that different mango cultivars presented different physico-chemical characteristics, which are important factors for evaluating the characterization of mango cultivars with regard to their nutritional value and potential use for different products.

Jamil *et al.* (2015) conducted a study at Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan during 2011-12 to evaluate eight mango cultivars (Almas, Collector, Pope, Neelum, SS-II, Shahpasand, Alphonso and Sindhri) for sensitivity to malformation and their differences relating to morphological, physiological and biochemical characteristics**.**

Cadena *et al.* (Brazil, 2013) carried out a study to determine the physicochemical characteristics and sensory profile of mango nectar sweetened with different high intensity sweeteners throughout storage time. The mango nectar samples were sweetened with: acesulfame K/sucralose/neotame blend (100:50:1), sucrose, stevia with 97% rebaudioside, neotame, sucralose and a thaumatin/sucralose blend (1:1). The physicochemical analyses carried out included colour (L*, a*, b*) and pH. The sensory profile was studied using the Quantitative Descriptive Analysis (QDA). All analyses were carried out at day zero, 60 days and 120 days of storage. The sensory descriptive and physicochemical data were correlated with an acceptance test by Partial least square (PLS) regression and External preference map (PREFMAP). Changes in sensory profile during storage time were also evaluated using Multiple Factor Analysis (MFA) and agreement between configurations was evaluated by Rv. coefficient.

Jilani *et al.* (2010) conducted a study of ten mango cultivars viz. Alphanso, Anwar Retual, Dusehri, Fajri, Gulab-e-Khas, Langra, Malda, Sanglakhi, Sindhri and Suwarnareeka which were evaluated in the Department of Horticulture, Faculty of Agriculture, Gomal University, D. I. Khan, Pakistan during 2006. Langra and Malda fruits matured earlier while fruits of Fajri and Sanglakhi matured late. Malda produced higher number of fruits per panicle (55) while Alphanso and Sanglakhi gave minimum fruits (22.67). Alphanso and Fajri produced longer fruits (15.20 and 14.43 cm) while

minimum fruit length was recorded in Anwar Retual (6.30 cm). Fajri excelled in fruit weight (455.9 g), seed weight (48.67 g), peel weight (84.99 g) and pulp weight (329.63g) as compared to all other cultivars. Suwarnareeka had higher percentage of pulp (92.40) while cultivar Gulab-e-Khas showed the lowest pulp percentage (61.41).

Nguyen *et al.* (2004) carried out an experiment with green mature mangoes (cv. Kensington pride) and treated with 0, 10, 100 and 1000 µg/ ml 1-1 ethylene at 90-95% relative humidity using a flow-through system at 15°C, 20°C or 25°C for 24h or 72h and then ripened at the same treatment temperature. They reported that at 15°C ripe fruit had more green colour on the skin compared to those at 20°C and 25°C with 72 hours treatment. However, increasing ethylene concentration resulted in significantly more green colour on the fruit skin and higher flesh acidity. The treatment, which resulted in the least amount of green colour on the skin of ripe fruit was 10 µg-1-1 ethylene at 20°C for 72h. They also recommended minimizing the amount of green colour in the ripe fruit temperature above at least 15°C and exposure to low ethylene concentration for about 72h.

Anila and Radha (2003) conducted an experiment for evaluation of physical and morphological characters of four varieties (Alphonso, Bangalora, Banganapally, Neelum) and two hybrids of mango (Ratna and H-151) were made under Kerala conditions at College of Horticulture, Kerala Agricultural University, Thrissur 680 656, India. It was observed that Ratna fruits had the maximum length, breadth, weight, volume and circumference. The minimum contribution of stone to fruit weight was in Ratna and the maximum in Muvandan. The overall perusal of the data revealed that hybrid variety Ratna had all the desirable characteristics in terms of length, breadth, weight, volume, circumference and minimum stone weight.

Vásquez-Caicedo *et al.* (January 8-11, 2002 at Chiang Mai, Thailand) carried out an experiment with nine Thai mango cultivars ('Chok Anan', 'Nam Dokmai', 'Rad', 'Mon Duen Gao', 'Kiew Sawoei', 'Okrong Kiew', 'Okrong Thong' 'Kaew' and 'Maha Chanok') which were evaluated in terms of their physical properties (size, mass, mesocarp yield, peel thickness, firmness and colour of peel and flesh) and sensory attributes at full maturity. This study is an approach to give a quality profile of Thai mango cultivars as well as their potential for technological and nutritional utilization considering availability, seasonal variability of quality as well as ripening behavior.

Gowda and Huddar (2001) carried out studies to determine the qualitative and quantitative changes in physiochemical characteristics of mango fruits during ripening by making use of eight mango hybrid or varieties. They found that the major changes during fruit ripening were reduction in fruit in weight (351 to 306 g), volume (338 to 309 ml), fruits length (11.04 to 10.55 cm), thickness (6.91 to 6.51 cm), firmness (28.96 to 17.46 lbs/sq. inch), pulp content (77.53 to 75.14%), pulp peel ratio (7.83 to 6.23). They also observed the changes in peel colour turning from light green, green or dark green to light yellow, yellow or orange-yellow, whereas pulp colour changed from white or pale yellow to yellow, deep yellow or orange yellow.

Rajput *et al.* (1999) studied physico-chemical changes occurring during fruit growth and development in mango cultivars Langra and Sunderja and hybrids Mallika and Amrapali. They observed that fruit growth followed a generally sigmoid pattern and was rapid between 30 and 90 days after fruit set. Fruits of Mallika and Sunderja registered higher pulp contents at harvest maturity. Specific gravity of the fruits showed a decreasing trend up to 45 days after fruit set and a linear increase in specific gravity was observed upto maturity of fruits in all the cultivars.

Aina and Oladunjoye (1993) studied post-harvest changes in fruit colour and pectinesterase and polygalacturonase activities in commercially mature, hard green mango fruits during storage under tropical ambient conditions (28 ± 1°C Temp. and 68 ± 2% RH). They observed that respiration showed a climacteric pattern attaining a peak of 99.37 ml CO_2 kg/h on day 5 of storage, while full ripeness was attained on day 10. Fruit firmness decreased as pectolytic activity increased with a reduction in deformation force from 49 KPa in unripe fruits to 25 KPa at the edible ripe stage.

An experiment was carried out by Mclauchlan and Wells (1992) with mangoes cv. 'Kensington' at different temperatures (3, 7, 10 or 13°C) for different storage periods (0, 2 or 3 weeks) and finally the fruits were ripened at 18, 22, 26 or 30°C temperatures. Results showed that fruits coloured significantly during first week of storage at 13°C temperatures remained static at 7°C and poorest colour was observed. Acidity of pulp increased by decreasing both storage and ripening temperatures. They concluded that the best ripening temperature was 22°C based on eating quality. Laborem *et al.* (1992) reported that cold storage led to less well developed colour but did not affect firmness.

Seymour *et al.* (1990) made low temperature storage trials mango cultivars 'Amelie', 'Kent' and 'Sensation' grown in Senegal. The fruits were harvested at various physiological maturities and stored at 12°C for period of up to 21 days. The response to storage at 12°C was dependent on cultivar, fruit maturity at harvest and harvesting date. The most apparent effect of fruit maturity on subsequent storage behavior was observed in 'Amelie'. Ripening was more effectively in immature than mature fruits.

Thangaraj and Irulappan (1988) conducted an experiment with fruit of the cultivars Neelum and Bangalora and sampled weekly over 8 weeks starting two weeks after fruit set. The fruits were graded into floaters and sinkers. They observed that the changes with time in ripening score and sinking percentage were markedly different in the 2 cultivars and the studies highlighted the difficulty of determining fruit maturity in mangoes of different fruit specific gravity.

Lee *et al.* (1988) conducted an experiment in central Taiwan both Chiin Hwang mango harvested at 93 days after full bloom and were placed at 25°C or 38°C for ripening. In another experiment fruits were gathered 102 days after anthesis and were stored at 28°C or 38°C, to compare the ripening process under different temperature. They observed Chiin Hwang fruits were under to complete the ripening process in up to 4 days at 25°C, while ripening was accelerated at 38°C. Two days after treatment (38°C), soluble solids increased to 11.2%, firmness and starch content decreased gradually as total soluble sugar concentration and alpha-amylase activity rose. Four days after treatment, pulp colour and flavour reached the stage of maturity but not skin colour. Those fruits picked at day 102 and stored at 28 or 38°C, had the same degree of maturity and were edible 4 days after temperature treatments. However fruits ripened at 28°C had a good skin and flesh colour, bright orange yellow at day 6. Those ripened at 38°C also possessed orange yellow skin but with green patches and some black spots appeared 8 days after treatments. They concluded that ripening at 28°C could retain a better post-harvest quality than ripening at 25°C or 38°C.

In a study on physico-chemical characteristics of some mango varieties, Bhuyan and Islam (1986) recorded the highest fruit weight (1014.45g) in fazli and the lowest (202.88g) in Kude-khirsapat. Wide range of variability among the varieties was recorded in fruit size, percentage of edible (64.94 to 81.49) and non-edible portions (18.51 to 35.06), stone sized and thickness of fruits (6.02 to 8.92 cm). Fazli was the longest fruit

(17.70 cm) and the shortest (8.26 cm) in Satiarkara. The highest breadth of the fruit (10.74 cm) was also observed in Fazli and that of the lowest (6.54 cm) in Fonia. The stone percentage of Gopalbhog was the highest (19.25) and that of Fazli was the lowest (8.07). The peel percentage varied from 8.87 to 9.32 among the studied varieties. The stone length ranged between 6.50 to 14.80 cm and breadth from 3.38 to 6.50 cm.

Medlicott *et al.* (1986) analyzed the pigments in the peel at 6 stages during ripening at 22°C. They found the loss of green colour and the development of yellow coloration was associated with an almost complete loss of chlorophyll a or 5-fold increase in carotinoids. They also reported that anthocyanin content decreased slightly during ripening. On ripening, chloroplasts under went extensive disorganization associated with the development of large osmophilic globules.

2.4 Bio-chemical and post-harvest changes during maturity or ripening stages

Souza *et al.* (2018) conducted an experiment at the São Manuel Experimental Farm, São Paulo State University (UNESP), Brazil to evaluate the physicochemical characteristics and bioactive compounds of mango fruits named Keitt and Palmer cultivars under subtropical conditions. Regarding chemical characteristics and bioactive compounds, titratable acidity, soluble solids, SS/TA ratio (relationship between soluble solids and titratable acidity), reducing sugars, non-reducer, total ascorbic acid, carotenoids, flavonoids, polyphenols and antioxidant activity were determined. The results showed that Palmer cultivar had higher chemical quality, which was observed in the values of SS/TA ratio, high antioxidant capacity, high ascorbic acid content, greater amount of total polyphenols, and suitable quantities of flavonoids and sugars.

Rasha *et al.* (December, 2016) carried out an experiment where selected physical and chemical quality attributes of three mango cultivars Kitchener, Abusamaka and Tommy Atkins were evaluated at ripening stage in the Faculty of Agriculture and Natural Resources, Department of Horticultural Science, El-Deuim– Sudan, during two successive seasons (2013 and 2014). Three mango cultivars (Tommy Atkins, Kitchener and Abusamaka) were collected from a private orchard in Kamlin (15˚ 04´N to 33˚11´E), central Sudan. The experiments were arranged in Complete Randomize Design (CRD) with three replications. Results showed that cultivars had significant differences in Ascorbic Acid, moisture content, total acidity, TSS, Ash and total sugar content in the two seasons. This study revealed that different mango cultivars presented different

physico-chemical characteristics, which are important factors for evaluating the characterization of mango cultivars with regard to their nutritional value and potential use for different products.

Ara *et al.* (2014) carried out a research to evaluate the nutritional properties of ten varieties (Amrapali, Chausa, Fazlee, Gopalbhog, Guti, Himsagor, Khirsapat, Kohitoor, Langra, and Mallika) of mango. Nutritional properties were significantly ($p < 0.05$) varied among the different mango varieties. The highest edible portion (79.49%), titratable acidity (0.75%) and calcium (30.56 mg/100 gm) were found in Gopalbhog. Highest amount of potassium (64.04 mg/100 gm) and magnesium (7.54 mg/100 gm) were found in Chausa while highest protein (1.18 gm/100 gm), crude fibre (4.78 gm/100 gm) and sodium (91.15 mg/100 gm) were found in Langra. Mango varieties contain significant amount of vitamin C (46.53-26.53 mg/100 gm), total sugar (5.48-4.27%) and total carbohydrate (27.33-4.49 gm/100 gm). The maximum calorific value (112.12 kcal/100 gm) was found in Amrapali. Heavy metal analysis was also done but no significant amounts were found. Present study thus strongly suggests that different varieties of mango can provide higher amount of vitamin C and important minerals that will be a sustainable health benefit.

Naz *et al.* (2014) conducted a study on Pakistani mango which is facing serious apprehension about production decline and export, consequently present study was planned to categorize the paramount mango (*Mangifera indica* L.) cultivar in relation to its physical, chemical and sensorial attributes. Physiologically fully mature fruits of eight mango cultivars were picked and subjected for physical and proximate analysis. Among the eight cultivars, Fajri produced the maximum green and ripe fruit weight, fruit length and perimeter and physiological weight loss (453.0g, 403.0g, 13.80 cm, 21.57cm and 10.97%), respectively. The higher softness values were noticed in Aman Dusahri. The mark variations were observed among all the cultivars for proximate composition. There is an increase in pH values (5.47, 5.40 and 5.33) among Samar Bahisht Chaunsa, Aman Dusahri and Anwar Ratual, respectively with a progressive decrease in ascorbic acid and titrable acidity during ripening period. Likewise, maximum moisture and ash contents were observed in the mango pulp of Fajri and Sindhri(92.20% and 0.78%, respectively). Whereas appreciably higher total sugar contents were observed in pulp of Langra, Samar Bahisht Chaunsa and Anwar Ratual 20.67%, 20.43% and 20.33%, respectively. 19.83 % TSS and 0.64% protein contents were recorded in Langra while the Fajri contained

higher fat contents. The sensorial attributes varied significantly according to cultivars. Out of eight cultivars Langra obtained higher scores, while Anwar Ratual found to be highly satisfactory followed by Samar Bahisht Chunsa for flavour and taste. Both of these cultivars were equally acceptable for overall acceptability. However, none of the cultivar is rejected by the panelists regarding the sensory evaluation.

Islam *et al.* (2013) was carried out a detailed study with the postharvest mangoes (namely, the Langra and the Khirshapat) treated with different levels of Bavistin DF (BDF) solution (namely, 250, 500, and 750 ppm) for obtaining results on biochemical changes as well as storability of postharvest mango. The experiment was laid out in randomized complete block design with three replicates. The results of the experiments exhibited that only the single effect of varieties was found to be significant in most of the parameters studied. The Langra enriched a greater quantity of titratable acidity and total soluble solid (TSS) at 3rd day, over the Khirshapat. On the other hand, Khirshapat showed increased pulp pH and TSS at all the storage duration. The results explored that some physicochemical properties, namely, pulp pH, TSS, sugar (total, reducing, and non-reducing), and titratable acidity along with shelf-life drastically decreased from untreated mangoes. Bavistin DF with the doses of 750 ppm showed better results in delaying the changes in physicochemical properties and extended shelf-life.

Cadena *et al.* (Brazil, 2013) carried out a study to determine the physicochemical characteristics and sensory profile of mango nectar sweetened with different high intensity sweeteners throughout storage time. The mango nectar samples were sweetened with: acesulfame K/sucralose/neotame blend (100:50:1), sucrose, stevia with 97% rebaudioside, neotame, sucralose and a thaumatin/sucralose blend (1:1). The physicochemical analyses carried out included colour (L*, a*, b*), pH, titratable acidity, soluble solids (°Brix) and ratio (Brix/titratable acidity). The sensory profile was studied using the Quantitative Descriptive Analysis (QDA). All analyses were carried out at day zero, 60 days and 120 days of storage. The sensory descriptive and physicochemical data were correlated with an acceptance test by Partial least square (PLS) regression and External preference map (PREFMAP). Changes in sensory profile during storage time were also evaluated using Multiple Factor Analysis (MFA) and agreement between configurations was evaluated by Rv. coefficient. Sucralose was shown to be the best substitute for sucrose when compared with the other high intensity sweeteners at both zero time and after 120 days of storage. The sample sweetened with sucralose showed

acceptance (mean at storage time 6.4) and sensory profile equal to control (sucrose). In addition, the sweeteners stevia with 97% rebaudioside did not show off-flavour and the thaumatin/sucralose blend (1:1) also presented similar acceptance (6.16 at Day zero) and sensory profile in relation to control.

Paddaa *et al.* (2011) carried out an experiment where Canonical discriminant analysis (CDA) was used to identify the best method to discriminate between maturity and ripening stages, assessed in terms of dry matter content, firmness, colour (peel and flesh), total soluble solids content attributes, before and during 'Keitt' mango ripening at 20°C. Canonical discriminant analysis showed that firmness with the penetrometer is the best tool to assess changes during mango ripen-ing followed by total soluble solids content and flesh a* value. The durometer was the most accurate non-destructive firmness method tested for mangoes. The microwave can be used as a quick method to analyze dry matter content to assess mango fruit maturity.

Jilani *et al.* (2010) conducted a study for biochemical characters of ten mango cultivars viz. Alphanso, Anwar Retual, Dusehri, Fajri, Gulab-e-Khas, Langra, Malda, Sanglakhi, Sindhri and Suwarnareeka which were evaluated in Pakistan during 2006. Among the cultivars, Gulab-e-Khas excelled in vitamin C and sugars. These chemical characteristics ranged from 131-179.7 mg/100g and 15-20 percent, respectively in the cultivars studied.

Shafique *et al.* (2006) conducted on a comparative study on physiological and biochemical composition of ten varieties of mangoes was carried out at three maturity stages viz. immature, mature and ripe to find out the standard one. During the investigation, whole weight of the mangoes, pulp content, weight of peel and stone, total soluble solid (TSS), pH, acidity, sugar content and vitamin C were determined at three maturity stages. It was observed that all the varieties at ripe stages had higher sugar content as compared to immature and mature stages. Attractive flavour and pleasant taste were also developed in ripe stages and differed from one another due to varietal specific. This characteristics odour which appeared during ripening is due to ester and components of carbonyl types.

Anila and Radha (2003) conducted an experiment for evaluation of biochemical characters of four varieties (Alphonso, Bangalora, Banganapally, Neelum) and two hybrids of mango (Ratna and H-151) were made under Kerala conditions in India. It was observed that fruits of hybrids Ratna and H-151 recorded the highest values of TSS,

sugar and ascorbic acid contents. The overall perusal of the data revealed that hybrid variety Ratna had the desirable characteristics in terms of TSS and sugar content.

Vásquez-Caicedo *et al.* (2002 at Chiang Mai, Thailand) carried out an experiment with nine Thai mango cultivars ('Chok Anan', 'Nam Dokmai', 'Rad', 'Mon Duen Gao', 'Kiew Sawoei', 'Okrong Kiew', 'Okrong Thong' 'Kaew' and 'Maha Chanok') which were evaluated in terms of their chemical composition (TSS, TA, TSS/TA, pH, pectin, fibre, sugars, organic acids, total phenols and β-carotene) and sensory attributes at full maturity. This study is an approach to give a quality profile of Thai mango cultivars as well as their potential for technological and nutritional utilization considering also characteristics such as vitamin C, availability, seasonal variability of quality as well as ripening behavior.

Gowda and Huddar (2001) carried out studies to determine the qualitative and quantitative changes in physiochemical characteristics of mango fruits during ripening by making use of eight mango hybrid or varieties. They found that the major changes during fruit ripening were reduction in fruit in acidity (2.71 to 0.04%), starch (10.7 to 0.43%) and vitamin C content (40.83 to 11.08 mg/100 g), and increase in peel (9.00 to 12.06%), TSS (8.55 to 19 % Brix), pH (2.85 to 4.38), total sugars (2.69 to 11.16%), sugar acid ratio (0.99 to 27.22) and carotenoids (498 to 8071 µg/100g).

Rajput *et al.* (1999) studied physico-chemical changes occurring during fruit growth and development in mango cultivars Langra and Sunderja and hybrids Mallika and Amrapali. They observed that titrable acidity increased after fruit set and then slowly decreased towards maturity. Ascorbic acid and moisture content of the fruits decreased after fruit set to maturity and maximum values were observed in cultivar Langra. However, TSS and total sugar content of the fruits showed an increase after fruit set up to maturity and they were highest in Langra and Sunderja, respectively.

The total sugar, sucrose and fructose contents of fruits were increased during storage as reported by Tsuda *et al.* (1999). However, maximum sugar content was observed in mango fruits at full ripe stage as reported by Takuji *et al.* (1997). Total sugar in Gopalbhog, Khiraspat, Langra and Fazli was found to be increasing at later stage of harvesting and this sugar contents further increased on storage of harvesting mangoes. In Fazli, the total initial sugar was 4-15% at 105 days after fruit set which was increased to 8.70% on ripening in storage, while after 127 days after fruit set the initial sugar content

5.02% increased to 15.98% on ripening in storage (Shahjahan *et al.* 1994) total soluble sugar content was the lowest (5.53%) in the fruit of Aswina as noted by Samad *et al.* (1975).

Absar *et al.* (1993) conducted a comparative study on the changes in the physico-chemical composition of ten mango varieties in Bangladesh at different stages of maturity. They reported that acidity continued to fall with the advances of maturity. Shahjahan *et al.* (1994) also reported the similar result from their experiment at mango research station, Chapai Nawabganj and showed that acidity declined gradually as the mango fruits advanced towards the ripening process. Srivastava (1967) reported from his experiment with 22 mango verities of various parts of India that acid content ranged from 0.67 to 3.66 in green mango and 0.18 to 0.56% in ripe mango fruit.

Aina and Oladunjoye (1993) studied post-harvest changes in fruit firmness, respiration rate, fruit colour and pectinesterase and polygalacturonase activities in commercially mature, hard green mango fruits during storage under tropical ambient conditions (28 ± 1°C Temp. and 68 ± 2% RH). They observed that respiration showed a climacteric pattern attaining a peak of 99.37 ml CO_2 kg/h on day 5 of storage, while full ripeness was attained on day 10. Fruit firmness decreased as pectolytic activity increased with a reduction in deformation force from 49 KPa in unripe fruits to 25 KPa at the edible ripe stage.

Absar *et al.* (1993) reported that TSS content increased markedly with advances in maturity. They reported that after ripened stage Langra showed the highest TSS (22.2%) and Fonia the lowest (16.8%). In an observation, Upadhyay and Tripathi (1985) reported that TSS increased gradually with ripening in cv. Gourjeet.

Absar *et al.* (1993) reported from their study that at an early stage of development sugar contents were maximum in the cv. Gopalbhog and minimum in Khirsapat and Kuapahari. Total sugar contents increased with maturity. They recorded the maximum total sugar in Langra (20.32%) followed by Gopalbhog (18.59%), Khirspat (18.52%) at the ripening stage. Shahjahan *et al.* (1994) also found an increasing trend of total sugar at later stage of harvesting. Mondal *et al.* (1995) also reported increasing trend of total sugar at the later stage of minimum of 8.1% and maximum of 23.08% total sugar on the 3rd and 12th day of storage, respectively by cv. Fazli. Similar trend was also found during ripening.

An increased reducing sugar during ripening was reported by Tripathi (1988). Various biochemical changes during storage of mangoes at various temperatures were reported by Agnihotri *et al.* (1963). According to them reducing sugars were changed little and then leveled off. Reducing sugar content decreased with the maturity of mango cv. Fazli and it was 4.23% as reported by Sarkar and Mushi (1978).

Yuniarti (1980) carried out an experiment in an attempt to investigate the pH content of mango fruits during storage and reported that the pH content of 'Arumanis' mango remained in an increasing fashion during storage. Joshi (1998) reported that there was a steady rise in pH of the fruits of 'Alphonso' mango during storage. The pH of fully ripe fruits of 'Fazli' was 4.64 as observed by Kumar *et al.* (1993). They observed that pH of mango pulp was increased during storage. Shahjahan *et al.* (1994) reported the pH content of 'Fazli' was 3.84 and 4.88 at harvest and last day of storage respectively. Salles and Tavares (1999) noted that pH of mango pulp increased during storage in a refrigerated room. The pH of hot water treated fruits was higher than non-hot water treated fruits (Zhu *et al.,* 2002).

Increased in the percentage of total soluble solids during storage in mango was reported by Singh (1968). Absar *et al.* (1993) found that the total soluble solid was increased with maturity of fruit. They found that 'Langra' showed the highest (22.2%) and 'Fonia' the lowest (16.8%) TSS content at ripen stage. Mollah and Siddique (1973) reported that 'Fazli' and 'Langra' exhibited 7.70 to 14.8% and 12.15 to 18.00% TSS, respectively. They also found that TSS varied from cultivars to cultivars and Ahmed (1994) recorded 18.3% TSS in 'Aswina'. Singh *et al.* (1998) conducted an experiment with mango cv. 'Amrapali' and observed that TSS contents at mature and ripe stage were 8.12 and 20.05%, repectively.

Leon and Lima (1968) reported that acidity in mango fruits reduced during later stages of growth, attainment of maturity and ripening. Yuniarti (1980) conducted an experiment in an attempt to study the physico-chemical changes of 'Arumanis' mangoes during ripening under ambient temperature and noted no significant differences in titrable acidity content during ripening.

Non- reducing sugar content was significantly higher at ripening stage than other stages as commented by Mazher (1960). They reported that Non- reducing sugar content of ripe fruits was 11-20%, whereas Popane (1939) reported that it was more than 20%. Samad *et*

al. (1975) observed that non-reducing sugar content was in the range between 1.62 to 6.60%. The non-reducing sugar content was the highest (6.6%) in the fruits of 'Misribhog' while it was lowest (1.62%) in the fruit of 'Aswina'. At ripening stage 'Fazli' contains 17.35% non-reducing sugar (Sarkar and Mushi, 1978). They also reported that high percentage of disaccharides (sucrose) and small amount of aldohexoses (glucoses and its isomer) were observed in ripe fruits.

2.5 Some other research work on mango fruits

Lauricella *et al.* (2017) carried out a research on mango. Historically, *Mangifera indica* L. cultivations have been widely planted in tropical areas of India, Africa, Asia, and Central America. However, at least 20 years ago its spreading allowed the development of some cultivars in Sicily, an island to the south of Italy, where the favorable subtropical climate and adapted soils represent the perfect field to create new sources of production for the Sicilian agricultural supply chain. Currently, cultivations of Kensington Pride, Keitt, Glenn, Maya, and Tommy Atkins varieties are active in Sicily and their products meet the requirements of local and European markets. Mango plants produce fleshy stone fruits rich in phytochemicals with an undisputed nutritional value for its high content of polyphenols and vitamins. This review provides an overview of the antioxidant, anti-inflammatory, and anticancer properties of mango, a fruit that should be included in everyone's diet for its multifaceted biochemical actions and health-enhancing properties.

Trivedi *et al.* (2015) investigated that Alphonso is the most delicious variety of mango (*Mangifera indica* L.) known for its excellent texture, taste, and richness with vitamins and minerals. The present study was attempted to evaluate the impact of Mr. Trivedi's biofield energy treatment on morphological characteristics, quality, yield and molecular assessment of mango. A plot of 16 acres lands used for this study with already grown mango trees. This plot was divided into two parts. One part was considered as control, while another part was subjected to Mr. Trivedi's biofield energy treatment without physically touching and referred as treated. The treated mango trees showed new straight leaves, without any distortion and infection, whereas the control trees showed very few, distorted, infected, and curly leaves. Moreover, the flowering pattern of control trees did not alter; it was on average 8 to10 inches with more male flowers. However, the flowering pattern of treated trees was completely transformed into compactone being 4 to 5 inches in length and having more female flowers. Additionally, the weight of

matured ripened mango was found on an average 275 gm, medium sized with 50% lesser pulp in the control fruits, while the fruits of biofield energy treated trees showed on average weight of 400 gm, large sized and having 75% higher pulp as compared to the control. Apart from morphology, the quality and nutritional components of mango fruits such as acidity content was increased by 65.63% in the treated sample. Vitamin C content in the treated Alphonso mango pulp was 43.75% higher than the pulp obtained from the control mango farm. The spongy tissue content in pulp of the matured ripened mangoes was decreased by 100 % for two consecutive years as compared to the control. Moreover, the yield of flowers and fruits in the treated trees were increased about 95.45 and 47.37%, respectively as compared to the control. Besides, the DNA fingerprinting data using RAPD revealed that the treated sample did not show any true polymorphism as compared to the control. The overall results envisaged that the biofield energy treatment on the mango trees showed a significant improvement in the morphology, quality and overall productivity along with 100 % reduction in the spongy tissue disorder. In conclusion, the biofield energy treatment could be used as an alternative way to increase the production of quality mangoes.

Chovatiya *et al.* (2015) performed a research entitled "Bio-chemical evaluation of mango (*Mangifera indica* L.) cv. Kesar at Saurashtra region" was carried out at Department of Horticulture and Food Testing Laboratory, College of Agriculture, Junagadh Agricultural University, Junagadh during the year 2013-14. Nine different locations from Saurashtra region were selected for this experiment *viz.*, Una, Mendarda, Bheshan,Junagadh (Sakkarbaug), Talala, Vanthali, Dhari, Aadityana and Ghogha. The harvested sample fruits from different locations were cleaned, ripened at room temperature in paper boxes, than used for further bio-chemical evaluation. The experiment was conducted in Completely Randomized Design. The myth has been proven to be real from this scientific study. From the conducted experiment over nine different locations, it can be concluded that the Talala is more congenial for mango cv. Kesar or it can be truly say that mango orchards located at/near Talala region produces better quality fruits as compared to others.

Hossain *et al.* (2014) performed a research to enhance the shelf-life of mango fruits and investigated the changes in biochemical parameters and activities of ripening associated enzymes of Ashwina hybrid mangoes at 4-day regular intervals during storage at −10°C, 4°C, and 30 ± 1°C. Titratable acidity, vitamin C, starch content, and reducing sugar were

higher at unripe state and gradually decreased with the increasing of storage time at all storage temperatures while phenol content, total soluble solid, total sugar, and nonreducing sugar contents gradually increased. The activities of amylase, α-mannosidase, α-glucosidase, and invertase increased sharply within first few days and decreased significantly in the later stage of ripening at 30 ± 1°C. Meanwhile polyphenol oxidase, α-galactosidase, and α-hexosaminidase predominantly increased significantly with the increasing days of storage till later stage of ripening. At −10°C and 4°C, the enzymes as well as carbohydrate contents of storage mango changed slightly up to 4 days and thereafter the enzyme became fully dormant. The results indicated that increase in storage temperature and time correlated with changes in biochemical parameters and activities of glycosidases suggested the suppression of α-galactosidase and α-hexosaminidase might enhance the shelf-life of mango fruits.

Islam *et al.* (2013) conducted an experiment on two popular mango varieties in Bangladesh (*viz.*, Langra and Khirshapat) and four different levels of Gibberellic acid (GA_3) solution, namely, control, 100, 200 and 400 ppm. The two factors experiment was assigned in randomized complete block design with three replicates. Data obtained from various biochemical analyses in terms of physicochemical properties and shelf-life of postharvest mango, were recorded and statistically analyzed for comparison among the mean values using Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD). The Khirshapat showed better performance in achieving higher quantity of moisture, progressively lost physiological weight, increased pulp pH, TSS after 6th day of storage, produced more quantity of sugar (total, reducing and non-reducing), as well as extended shelf-life and delayed skin colour changes than Langra at all the storage duration. Different levels of GA_3 solution subjected to the investigation demonstrated significant variation in most of the physicochemical properties and shelf-life of mango at different days after storage. The results explored that some physicochemical properties *viz.,* physiological weight loss, moisture content, pulp pH, TSS, sugar (total, reducing and non-reducing), were rapidly increased from untreated mangoes. GA_3 at 400 ppm showed better performance in delaying the changes in physicochemical properties and extended shelf-life.

Guzmán *et al.* (2013) investigated an experiment to study the composition and chemical characteristics of Mexican mangoes (*Mangifera indica* L.) of Nayarit, mature and without application for human intake. During the first experimental stage, the influence

of the harvest beginning and ending (June and August) on the shell, seed and pulp of four representative samples from 96 mature fruits reduced to twelve per season was assessed. The mangoes were from the Tommy Atkins variety, randomly collected the same day in two markets and two allotments (twelve fruits/place). In the second, a factorial scheme 2 x 3 was used to study the effect of season and components on the mangoes' chemical characteristics. There was no season effect either on the fresh weight of the fruits (417 and 454 g) or the pulp percent (76.1 and 75.8%). However, the shell and seed proportion increased and diminished lightly ($P < 0.05$) in August compared with June. There was no significant effect on the interaction season x component in the chemical indexes. The season did not influence on the DM content of the fruit (average, 26.4%), but did on the NDF and N content, which tended to increase ($P < 0.05$) in August in respect to June. The NDF content was different ($P < 0.05$) in shell, seed and pulp (40.1, 56.5 and 66.6%). The N level was lower ($P < 0.05$) in shell (0.48%) than in seed and pulp (1.2% in both cases), and was always low. It is suggested that the mango parts, considered as waste in the industry (shell and seed) can be a good resource for ruminants' feeding. There are no evidences that the beginning and ending of harvest influence on the chemical and chemical characteristics of the fruits.

Shobana and Rajalakshmi (2010) investigated that the Subject of food science & Nutrition is an engrossing one. Based on this aspect the study aims to analyze the nutrients present in unripe mango (*Mangifera indica*) and in the seed. It was essential to compare the analytical data of nutrients present in ripe mango. In this study seven nutrients were analyzed.

Othman and Mbogo (2009) conducted an experiment of two mango (*Mangifera indica* L.) fruit varieties, Dodo and Viringe, from two localities of Eastern Tanzania, (Muheza in Tanga and Ifakara in Morogoro) to analyze for their proximate composition (ash, titratable acidity, crude fat, crude fibre, moisture), reducing and total sugars content, ascorbic acid and total soluble solids content, concentration of four macro elements (Ca, Mg, K, Na) and seven heavy metals (Al, Cd, Cu, Fe, Mn, Pb, Zn). Fruits were harvested as mature green fruits during early, mid and late season and allowed to ripen while stored at room temperature. The results showed that the mango fruits had high moisture content (>65%), moderate acidity (0.20 - 1.30% c.a.), low crude fat content (0.20 g/100 g-fw), low crude fibre content (0.85 g/100 g-fw), low ash content of 0.55 g/100 g-fw, high reducing sugars amounts (10.5 – 21.3%), high total sugars content (10.5 – 21.3%), high

soluble solids content (14.2 – 26.5%) and high ascorbic acid content (15.8-25.1%). Potassium was the major macroelement present (209.5 mg/100 g-fw). Heavy metal concentrations in the fruits were very low indicating insignificant pollution of the fruits. Moisture, reducing sugars, total sugars, and soluble solids content in the mango fruits increased within the season and with ripening storage. The ascorbic acid and titratable acidity content increased as the season progressed but decreased during the storage ripening period. Minimal seasonal changes were observed for ash, crude fat and crude fibre contents of the fruits.

Paul and Shaha (2004) conducted a study on seventeen different common citrus fruits have been analyzed for their content of nutrients: carbohydrates, proteins, lipids, vitamins, β-carotene, thiamine, riboflavin, ascorbic acid, important macro and micro minerals such as sodium, potassium, calcium, magnesium, phosphorous, iron, zinc and copper. Carbohydrate, protein and fats in citrus fruits varied from 4.60-8.50, 5.80-7.90 and 2.50-9.50 g, respectively. The content of β-carotene, thiamine, riboflavin and ascorbic acid varied different amounts in citrus fruits. The highest contents of β-Carotene fruits are orange and tomato. Among the analyzed citrus fruits pineapple content, the maximum amount of thiamine (0.20 mg/100 g) and wood apple content maximum riboflavin (0.15 mg/100 g). Amla (Indian gooseberry) fruits contents the highest ascorbic acid 600 mg/100 g of fresh edible parts of fruits. Lemon contained the highest amount of calcium. The highest amount of magnesium was found in Black berry (49.80 mg/100 g of edible portion of the fruits). Sodium present in different citrus fruits ranged from 1.0 to 28 mg/100 g. Wood apple contained the highest amount of phosphorous (98.90 mg/100 g) among all citrus fruits. Tomato contained the highest amount of Potassium (275 mg/100 g). The iron content in different fruits ranged from 0.10 to 38 mg/100 g. Zinc present in fruits ranged between 0.18 to 0.48 mg/100 g. Copper content in different fruits analyzed ranged from 0.1 to 0.68 mg/100 g of fruits.

Reddy and Haripriya (2002) reported that mango fruits treated with GA_3 and stored in polyethylene bags with ethylene absorbent significantly reduced physiological weight loss. Physiological weight loss was reduced in fruits of mango cv. 'Kensington pride' which were wrapped with polyethylene bags and stored in 13°C (Zora *et al.,* 2001).

Malundo *et al.* (2001) conducted an experiment where mango (*Mangifera indica* L.) flavour perception were analyzed to determine the effects of varying sugar and acid

concentrations on flavour properties of mango to better understand how flavour components impact our sensory perceptions. Twelve treatments, identified using a constrained simplex lattice mixture design, were formulated by adding sugar (60%), citric acid (40%), and water to an equal volume of mango homogenate. Using 150-mm nonstructured line scales, a trained panel evaluated the treatments according to 11 flavour descriptors. Titratable acidity (TA), pH, and total soluble solids (TSS) were also determined. Acid concentration affected ratings for sweet, sour, peachy, pine/terpentine, astringent, and biting. Except for sour taste, all descriptors were affected by sugar content while increasing water increased intensities of all flavour notes. TA, pH, and TSS/TA correlated ($P < 0.01$) with and were useful predictors ($r > 0.80$) of sour taste and chemical feeling descriptors astringent and biting. TSS, however, was not a particularly good indicator of sweetness ($r = 0.72$) or any other descriptor except possibly peachy ($r = 0.79$). Determining the relationship of chemical measures to sensory data would allow their use in lieu of sensory studies to predict certain flavour properties. It was evident from this study that sugars and acids enhance human perception of specific flavour notes in mango, including aromatics.

Jain *et al.* (2001) found that the post-harvest application of wax emulsion (8%) and calcium nitrate (1%) in combination with cool chamber storage markedly reduced the rate of ripening and helped to retain the quality characteristics of fruits during storage. At the end of the storage period minimum total soluble solid, total sugar and reducing sugar contents and maximum acidity were recorded for wax emulsion + cool chamber storage. Maximum ascorbic acid and highest organoleptic score were obtained with calcium and cool chamber storage.

Shauggnan-Guolian *et al.* (2001) conducted an experiment on post-harvest ripening of mango as mango production under the condition of air pollution appeared to be a new problem. They found that mango fruits treated with 0.5% ethylene solution at 50°C for 5 minutes and kept in air conditioned room with ethylene for 16h and thereafter stored in ambient temperatures, exhibited enhanced ripening process and improved eating quality. Compared with unpolluted control fruits, respiration rate of polluted mango fruits was lower and had no peak. They also found that membrane permeability of the pulp, fruit firmness and peel colour changed simultaneously with the respiration rate.

Osthuyes *et al.* (2000) studied the storage behavior of mango fruits cv. 'Sensation' and 'Tommy Atkins'. The mangoes were placed in cool storage (12.5°C for 28 day) 12, 36, 60, or 84 h after harvest. Shelf-life was higher of the fruits in the cold storage, but it decreased with delay prior to storage.

Salles and Tavares (1999) carried out an experiment to study the effect of storage temperature on storage period and physico-chemical characteristics of mango cv. 'Tommy Atkins'. The fruits were stored in a refrigerated room for 15 or 30 days. Another batch of fruits was stored at room temperature.

Pal (1998) investigated the effects of Ethrel (Ethephon) (500, 1000 or 1500 ppm) and calcium carbide ripening and textural changes of fruits of mango cv. Rataul. He observed initiation of ripening was faster in Ethrel and calcium carbide treated fruits than in untreated fruits. Fruits treated with Ethrel at 1000 ppm showed the best ripening attributes and sensing quality. Unfretted fruits exhibited the highest variation in pulp texture due to uneven ripening. Ripening was initiated from the periphery and proceeded towards the centre. Ethrel treatment slightly promoted physiological weight loss. They also observed the highest percentage of rotted fruits was observed in the calcium carbide treatment. Ascorbic acid content was reduced in the calcium carbide treatment compared with the others.

O'Hare (1995) conducted an experiment with preclimacteric mango cv. Kensington and fruits were treated with ethylene (200 µl/l) for 36h, then ripened at 13, 18, 22, .4, or 30°C or under 2 day/night temperature regimes (18/24°C in 12/12-h or 18/6-h cycles). He observed that fruits ripened at 18-22°C achieved the highest quality scores, with all quality parameters reaching a maximum within about 2 days of each other. Diurnal temperature cycling provided no advantage over constant temperatures. Fruits ripened at 13 or 30°C had low skin colour quality scores, related to poor carotenoid development and high chlorophyll retention, respectively. He also reported that eating quality was significantly lower at 13 and 30°C than at intermediate temperatures, related to the slow decline in titrable acidity and poor flavour, respectively. Quality parameters became unsynchronized at 13 and 30°C with skin colour quality reaching a maximum 5 days earlier than eating quality at 13°C and 3 days later at 30°C.

There is no available literature dealing with the changes in dry matter content of mango fruits during storage. However, Paramanik (1995) found that dry matter content in Fazli increased from 17.14 to 28.86% during storage in ambient temperature. It is evident that as repining progress some carbohydrate is completely oxidized to CO_2 and water as a result of respiration (Palmer, 1971). This indicated an actual decrease in dry matter content.

Inyang and Agbo (1995) reported that mango cv. Julie fruits were harvested at the mature green stage and dipped in hot wood ash at 55°C, then left to ripen at ambient temperature in cardboard cartons. They observed, compared with a control the treatment led to slightly higher contents of sugars, ascorbic acid and carotenoids.

O'Hare and Prasad (1993) studied the effect of low temperature (5, 7, 10, or 13°C) and controlled atmosphere (0, 5, or 10% CO_2 and 5 or 21% O_2) storage of mango fruits cv. 'Kensington'. Fruits were released from different treatments after 0, 1, 3 and 5 weeks of storage and ripened at 22°C temperature for 7 days. Skin browning was reported at 5°C temperature but no such browning was observed at high temperatures. At 7°C temperature, pulp was depressed significantly and titratable acidity was increased after three weeks of storage. At 13°C temperature, fruits were over ripen and titratable acidity was in declining fashion after 5 weeks of storage. Results indicated that 'Kensington' mango could be stored at 10°C temperature without any danger of serious chilling injury.

Absar *et al.* (1993) analyzed ten varieties of mango at different stages of maturity and reported that ash content ranged from 0.54 to 0.94% in ripe fruit.

Absar *et al.* (1993) reported that moisture content at the early stage of development varied from 87.4 to 90.1% gradually decreased as the maturity advanced and at ripening stage, it varied from 71.22 to 79.4%. Shahjahan *et al.* (1994) also reported that moisture content of pulp of mature hare mango was 79.95% but Bhatnargar and Subramanyam (1973) recorded it as 91% and in ripe mango 74-86%. Mondal *et al.* (1995) reported a decreasing tendency of moisture content towards ripening during storage ranging from 81.6 to 90.0% on 3rd day and 12th day of storage.

Weight loss was reduced when mango fruits were stored in polyethylene bags as reported by Wavhal and Athale (1989), Shrivarma and Thimmaraju (1989). Gonzalez *et al.* (1990) also reported that modified atmosphere packaging with polythene bags delayed ripening

and reduced weight loss. Manzano *et al.* (1997) found that 6.2 percent fresh weight loss of mango fruits occurred when stored at 25°C temperature for 20 days.

Thangaraj and Irulappan (1988) reported that cool chamber storage of 'Neelum' mango had prolonged shelf-life. Many mango varieties if picked at fully mature stage could be stored for about 4 to 7 weeks at a temperature ranged from 3.9 to 8.9°C (Cheema *et al.,* 1950 and Karmakar and Joshi, 1942). A work at Mysore has shown that most varieties are best stored at 5.6°C to 5.2°C with 85 to 90% RH, which for some other varieties a temperature of 8.9 to 11.1°C may be suitable (Srivastava, 1967). Even the same variety grown at different places may behave differently under cold storage (Singh *et al.*, 1953). The storage life of 35 days was found in case of 'Alphonso' mango at 8.3 to 10.0°C and in case of 'Raspuri' it was 4.9 days at a temperature of 5.6 to 7.2°C in 7.5% CO_2 atmosphere with 10% wastage as reported by Kapur *et al.* (1962).

Lertpuk (1988) observed that great variations in post-harvest characteristics of mangoes were only obtained when the conditions in storage were modified. Storage at 10°C for 3 weeks prior to ambient storage (32°C) significantly extended the post-harvest life of the fruits. However, fruit ripening was adversely affected. Although the fruit had a longer ripening period, their edible ripe life was markedly shortened compared with fruit continuously held at ambient temperature from harvest.

Ahmed *et al.* (1988) carried out an experiment to study the effects of storage duration on the organoleptic qualities of 'Ashwina' mango of Bangladesh at low temperature. Fruits were stored at 11 to 28°C with 90 to 95% relative humidity in cold storage for duration of 0, 15, 30, 45, 60, 90 and 150 days at Hathazari, Chittagong. Different fruit characters such as weight loss, flesh consistency, aroma, skin colour, sweetness and juiciness of fruit pulp remained for the first 15 days at the end of specific storage duration with 3.8% weight loss. The edibility and juiciness were retained to an acceptable limit up to a maximum storage period of 45 days. There being complete deterioration of all fruit attributes beyond 45 days of storage.

Mango stored inside the refrigerator throughout the storage period had significantly the longest storage life of 28.33 days as reported by Dipasupil (1984).

Singh (1960) reported that the post-harvest losses of mango fruit in India due to microbial decay ranged from 20 to 30%. Quality mangoes are produced in north-western

part of Bangladesh, of which about 35 to 38% post-harvest losses are caused due to inefficient handling during its ripening, transportation, storage and marketing (Rubbi *et al.*, 1985). Mondal *et al.* (1995) estimated that post-harvest loss of mango was in the range of 30 to 35%. The post-harvest loss of fruits per year including mango has been estimated to be 0.226 million tons and these were valued at Tk. 135.60 crore (Sams-Ud-Din, 1997).

CHAPTER 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the materials and methods used to carry out the present research work. The materials and methods were used to determine the physico-chemical characteristics of some indigenous cultivars of mango. The details of the methodology of the study followed during the research period are presented in this chapter.

3.1 Experimental site

The lab-based experiment was conducted at the laboratories of Horticulture, Food Processing and Preservation and Agricultural Chemistry, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur.

3.2 Experimental time

The experiment was conducted during June, 2017 to July 2017.

3.3 Experimental materials

The fruits of 13 indigenous cultivars of mango were chosen from the well-managed orchard situated in the village Teroroshia, upazila Shibganj under Chapai Nawabganj district (Table 1 and Plate 1). The maturity of mango was detected by the actual individual shape and size of fruits i.e. when the shoulders were in line with the stem end and the colour was olive green. A brief description of thirteen mangoes is given below:

Table 1: Name, size and time of harvest of 13 indigenous cultivars of mango

Cultivar	Cultivar name	Size	Time of harvest
V_1	Monmohan	Medium	2 June, 2017
V_2	Kheermohan	Large	2 June, 2017
V_3	Golapbaas	Small	2 June, 2017
V_4	Lakhno	Large	18 June, 2017
V_5	Haaji	Large	18 June, 2017
V_6	Sonamohan	Medium	18 June, 2017
V_7	Kalibhog	Medium	18 June, 2017
V_8	Madhuchuski	Large	18 June, 2017
V_9	Bhaaduria	Very large	7 July, 2017
V_{10}	Koitori	Large	7 July, 2017
V_{11}	Kuapahari	Medium	7 July, 2017
V_{12}	Phunia	Medium	7 July, 2017
V_{13}	Belbhog	Medium	7 July, 2017

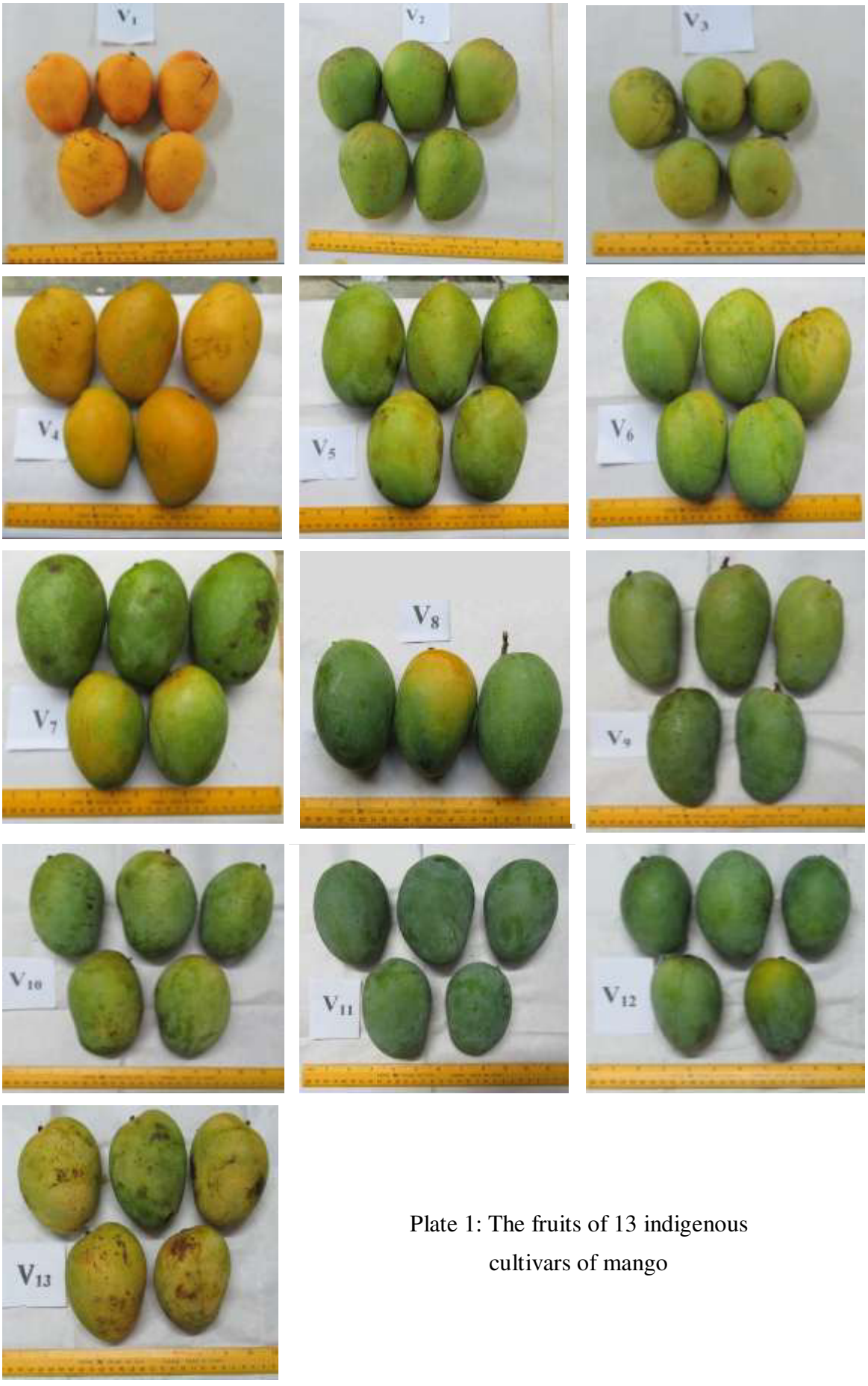

Plate 1: The fruits of 13 indigenous cultivars of mango

3.4 Collection of experimental sample

The fruits of 13 indigenous cultivars of mango were collected from the well-managed orchard of Chapai Nawabganj district for this experiment. Among the samples, the first three mature early-cultivars were harvested early in the morning on 2nd June, 2017. Whereas fruits of medium and late cultivars were harvested on 18 June and 7 July, 2017, respectively. The harvested mangoes were transported immediately with care from the orchard to experimental laboratory on the same day of harvest. During transportation, mangoes were packed using crate. Thereafter, mangoes were kept for ripening at room temperature (30.2 - 35.9°C, relative humidity 65-70%) for 3 - 5 days. After taking the physical parameters, the pulp of mangoes were stored in refrigerator at -80°C temperature for further chemical analysis.

3.5 Experimental design and replications

The lab-based experiment was conducted in Completely Randomized Design (CRD) with five replications. For all measurements of physico-chemical analysis, randomly five fruits were used in the present experiment.

3.6 Parameters studied

The mangoes were observed for physico-chemical characteristics i.e. their external features and chemical characteristics such as pH, total soluble solids, vitamin C, total polyphenols, sugar, β-carotene etc. For these analysis, all the determinations were done in five times and the results were expressed as average and have been presented both in percentage and in acceptability scores. The following physico-chemical parameters were studied in the present experiment:

3.6.1 Physical parameters

3.6.1.1 Length of fruit (cm)

The length of fruits was recorded in cm individually from the proximal end (site of stalk) of a fruit up to the distal end (site of apex) using an electrical digital caliper (Guanglu, China).

3.6.1.2 Diameter of fruit (cm)

The fruit diameter was recorded in cm using an electrical digital caliper (Guanglu, China) at the middle part of the fruit.

3.6.1.3 Individual weight of fruit (g)

The weight of fruits was measured using an electronic balance (G G, T100, Germany) and expressed in gram (g).

3.6.1.4 Weight of pericarp (g)

The pericarp weight was also measured in g using an electric balance (G G, T100, Germany).

3.6.1.5 Weight of stone (g)

The weight of stone was measured in g using an electric balance (G G, T100, Germany).

3.6.1.6 Weight of pulp (g)

An electric balance (G G, T100, Germany) was used to measure the weight of pulp in g.

3.6.1.7 Fruit pulp and stone ratio (weight basis)

This ratio of fruit pulp and stone was measured by weight basis.

$$\text{Fruit pulp and stone ratio} = \frac{\text{Weight of pulp (g)}}{\text{Weight of stone (g)}}$$

3.6.1.8 Pericarp and pulp colour of fruit (L, C and H°)

The colours of the pericarp and pulp of the fruits were recorded using a Chromameter (Konica Minolta CM 250d, Japan) calibrated against a standard white plate (Plate 2). The chromatic analysis was carried out following the Commossion International de I'Eclairage system (CIE, 1976). The values of L*, a* and b* were measured to describe a three dimensional colour space and interpreted as follows: L* indicates lightness, read from 0 (completely opaque or "Black") to 100 (completely transparent or "White"). The positive a* value indicates redness (negative a* indicates greenness) and the positive b* value yellowness (negative b* value indicates blueness) on the hue-circle (Hutchings, 1994 and Voss, 1992). It was decided to express both the pericarp and pulp colour in terms of L, Chroma (C*), Hue angle (H°). The purple colour development of the fruit was better described using C* and H° than a* b*. The hue angle (H*), hue= arctangent (b*/a*), represented red-purple (0°), yellow (90°), bluish-green (180°) and blue (270°) (McGuire, 1992). The chroma (C*), obtained from $(a^{*2} + b^{*2})^{1/2}$, corresponded to the intensity or colour saturation in which the low values represent dull colour while high on represent vivid colour. In this experiment, both the pericarp and pulp colour was

measured from central portion of both sides of each fruit. The data of each measurement were the average of duplicate measurements at two opposite points of each fruit.

Plate 2: Chromameter

3.6.1.9 Firmness (kg/cm^2)

Firmness is expressed as the force required to penetrate the fruit by a 1.6 cm-diameter conical needle penetrating to the depth of 1 cm using a penetrometer (Handpi, China) (Plate 3). A mango fruit was taken and the needle of the penetrometer was penetrated into it, the maximum force to penetrate the fruit sample was recorded as the firmness. Two measurements were made on the pericarp of each fruit: one at the proximal pericarp, and the other at the central region of the pericarp. The recorded data were averaged to calculate the mean value.

Plate 3: Penetrometer

3.6.1.10 Shelf-life of fruits (days)

The fruits of 13 indigenous mangoes were harvested and stored at room temperature (30.2 - 35.9°C, relative humidity 65-70%) by using plastic crates with perforation and traditional paddy straw as ripening material. For shelf-life study, 10 fruits of each cultivar were stored on 2.5 cm thick paddy straw. Shelf-life of mango fruits was

calculated by counting the number of days required from harvest to ripen fully with retained optimum marketing and eating qualities.

3.6.2 Chemical parameters

3.6.2.1 Total Soluble Solids (TSS)

To characterize the maturity and quality of the fruits, the total soluble solids (TSS) were determined. The TSS content of the mango pulp was estimated using a digital refractometer (Hanna Instruments, Romania). One drop of the mango juice, squeezed from the fruit pulp, was placed onto the refractometer prism plate and lid was closed. The reading on the prism scale was noted up to one decimal place. After each test, the prism plate was cleaned with distilled water and wiped dry with a piece of soft tissue paper. Finally, the recorded data were averaged to calculate the mean value and TSS was expressed as % Brix directly from the scale at room temperature (30 ± 2°C).

3.6.2.2 Pulp pH

The pH value of mangoes pulp was measured according to the method AOAC (2000). A digital pH meter (HANNA pH 211 Microprocessor pH meter, Romania) was used to determine the pH value of the sample by performing two point calibrations (with buffer 7.0 and buffer 4.0) before measuring the sample pH.

3.6.2.3 Vitamin C content (mg/100g fw)

Vitamin C content was determined by the spectrophotometric procedure (Bajaj and Kaur, 1981) in mg/100 g fresh weight. Five grams of the fresh tissue were homogenized with a homogenizer (VELP Scientifica, Italy) in 100 ml oxalic acid-EDTA (Ethylene di amine tetra acetic acid) cold solution (Plate 4). The homogenate was then centrifuged at 3000 rpm for 10 minutes at 4°C and the supernatant was subsequently filtered with filter paper (Whatman No. 1). A 5 ml aliquot was then transferred to a 25 ml volumetric flask to which 0.5 ml metaphosphoric acid (Merck, Germany)-acetic acid solution, 1 ml sulphuric acid solution (5%) and 2 ml of ammonium molybdate (Merck, Germany) (5%) reagent were added. The mixture was adjusted to a volume of 25 ml distilled water and allowed to stand for 15 minutes. After that the absorbance at 760 nm was measured with a UV-VIS spectrophotometer (PG Instrument Ltd. Model T60, UK). Vitamin C concentration was quantified using a standard curve of L-ascorbic acid and expressed as mg/100 g fresh weight (fw).

Plate 4: Homogenizer

3.6.2.4 Determination of total soluble sugar, reducing sugar and non-reducing sugar

Preparation of fruit extracts

Fruit extract for total soluble sugar and reducing sugar analysis was prepared according to the method described by Saadati *et al.* (2013) with few modifications. At first, 500 mg fresh fruit pulp was taken in a 50 ml beaker. Afterward, 10 ml of 80% ethanol solution was added to it and homogenized. Then, the solution was centrifuged at 2000 rpm for 20 minutes. The extraction solution was prepared freshly on each analysis day.

Preparation of DNS (3, 5-di-nitro salicylic acid) solution

One gram of NaOH was taken in a 100 ml beaker and 70 ml deionized water was added to it. Afterward, 18.2 g sodium-potassium tartarate (Merck, Mumbai, India) was dissolved in the solution. After dissolving, 1 g of 3, 5-di-nitro salicylic acid (DNS) was added with it and stirred continuously. Then, 0.05 g Na_2SO_3 and 0.2 g phenol were dissolved with the solution, respectively.

3.6.2.4 (a) Determination of total soluble sugar content (mg/100 ml)

The total soluble sugar content of mango fruits was determined by using the method of Dubois *et al.* (1956). For this, at first 2 ml of supernatant was mixed with 1 ml of 5% phenol solution. Subsequently, 5 ml of 95.5% sulphuric acid was added to the samples. The test-tubes were then allowed to stand for 10 minutes and vortexed for 30 seconds. The test- tubes were kept in water bath at room temperature for 20 minutes for colour development. Finally, the absorbance was recorded using UV-VIS spectrophotometer (PG Instrument Ltd. Model T60, UK) at a wavelength 490 nm. Standard curve for the

total soluble sugar determination was constructed by using glucose solutions whose concentrations ranged between 0 to 0.25 mg/ml.

3.6.2.4 (b) Determination of reducing sugar content (mg/100 ml)

Content of reducing sugar in the tissue of mango fruits were analyzed by following the method suggested by Miller (1959). In a test tube, 0.5 ml fruit extract was mixed with 0.5 ml of DNS solution. The mixture was then boiled for 10 minutes and cooled by immersing the test tube containing samples in cold water. 5 ml of de-ionized water was then added to the test tube and mixed well. Afterward, the absorbance was taken at 540 nm in a UV-VIS spectrophotometer (PG Instrument Ltd. Model T60, UK). The standard curve was developed by using glucose solutions whose concentrations ranged between 0 to 1.2 mg/ml.

3.6.2.4 (c) Determination of non-reducing sugar content (mg/100 ml)

Non-reducing sugar content of the mango fruits was determined by subtracting the reducing sugar content from the total soluble sugar content by using the following formula:

Non-reducing sugar content (mg/100 ml) = Total soluble sugar content – Reducing sugar content

3.6.2.5 Beta-Carotene content (mg/100 g fw)

Beta-carotene in mango pulp was determined according to the method of Nagata and Yamashita (1992). One gram of pulp was mixed with 10 ml of acetone: hexane mixture (4:6) and vortexed for 5 minutes. Then the mixture was filtered through Whatman No.1 and afterward the absorbance was measured at 453 nm, 505 nm, 645 nm and 663 nm. Beta-carotene content was calculated according to the following equation-

$$\beta\text{-carotene (mg /100ml)} = 0.216\, A_{663} - 1.22\, A_{645} - 0.304\, A_{505} + 0.452\, A_{453}$$

(A_{663}, A_{645}, A_{505} and A_{453} are absorbance at 663 nm, 645 nm, 505 nm and 453 nm each other)

3.6.2.6 Total polyphenol content (mg GAE/100 g fw)

Total phenolic compounds were quantified using Folin-Ciocalteu reagent (FC) and the colorimetric method of Singleton and Rossi (1965). The extrction was performed according to Velioglu *et al.* (1998) using 1 g mango flesh. The mango tissues were

disrupted into the extraction medium using a homogenizer (Plate 4). The flesh was extracted with 4 ml 80% aqueous methanol containing 2.7% HCl (37%), shaken for 2 hours on an orbital shaker at 200 rpm and centrifuged at 5300 rpm for 15 minutes at 4°C (Plate 5, 6). The extraction procedure was repeated twice and the supernatants were combined for the total phenolic assay. Three hundred microliter (300 µl) of the extract was added to 2.25 ml of Folin-Ciocalteu reagent followed by 2.25 ml of sodium carbonate solution (60g/l).

The samples were vortexed and left to stand for 90 minutes at the room temperature. After incubation, the absorbance was measured at 765 nm using a UV-VIS spectrophotometer (PG Instrument Ltd. Model T60, UK). The phenol contents were then estimated from the standaed curve of gallic acid (Merck, Germany) and the results were expressed as mg of gallic acid equivalents (GAE)/100 g fresh fruit weight basis.

Plate 5**.** Orbital shaker

Plate 6. Centrifuge Machine

3.7 Statistical analysis

One factor analysis of variance (ANOVA) was performed for all the variables using the statistical program (STSC, 1987) Statgraphics plus Version 2.1. The means were compared using Fisher's Least Significant Difference (Lsd) test.

CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was carried out to assess the physico-chemical characteristics of some indigenous cultivars of mango. A summary of the analyses of variance of all the characteristics studied together with their sources of variations and corresponding degrees of freedom are shown in the appendices. The data on different parameters were analyzed and the results are summarized in tables and figures. The results of each parameter have been presented, discussed and possible interpretations are set in this chapter.

4.1 Length of fruit (cm)

The length of fruit ranged from 84.57 to 133.79 cm and a significant variation was observed among the cultivars (Table 2 and Appendix I). It was further observed that Bhaaduria (V_9) produced the longest fruit (133.79 cm) whereas Golapbaas (V_3) produced the shortest (84.57 cm) one which was about one and half time less than Bhaaduria.

Variation in fruit length is a genetic attribute. In the present study, it was observed that Bhaaduria had the highest fruit length and Golapbaas had the lowest one most probably due to their varietal characteristics. Similar variation in fruit length of different mango cultivars was also studied by different authors (Rasha *et al.*, 2016; Jilani *et al.*, 2010; Gowda and Huddar, 2001 and Bhuyan and Islam, 1986).

4.2 Diameter of fruit (cm)

The average diameter of fruits showed marked differences among themselves which ranged from 54.73 to 76.51 cm (Table 2). However, the differences significantly varied among themselves (Appendix I). In case of the diameter of fruit, Kheermohan (V_2) had the highest diameter (76.51 cm) which was statistically similar with Lakhno (V_4) while the lowest diameter was in Golapbaas (V_3, 54.73 cm) and it was about 1.5 times less than the superior (Table 2).

From the study, it was observed that fruit diameter depends on the length of fruit. The Golapbaas had the lowest length and diameter than the other cultivars. On the other hand, Kheermohan had the highest diameter possibly because of their moderate length among the mango cultivars. Souza *et al*. (2018), Rasha *et al.* (2016), Gowda and Huddar

(2001) and Bhuyan and Islam (1986) also found similar significant differences in diameter of fruit of different mango cultivars.

Table 2: Length (cm), diameter (cm), weight of pericarp (g) and weight of stone (g) of different mango cultivars

Cultivar	Length of Fruit (cm)	Diameter of fruit (cm)	Weight of pericarp (g)	Weight of stone (g)
V_1	96.78 de	61.50 e	42.43 gh	35.47 fg
V_2	115.05 b	76.51 a	74.13 c	59.77 ab
V_3	84.57 f	54.73 f	38.93 h	30.17 g
V_4	117.78 b	73.96 ab	80.63 b	40.60 f
V_5	115.85 b	68.76 c	43.63 g	52.77 bcd
V_6	95.53 e	71.34 bc	62.10 d	42.57 df
V_7	100.55 cde	69.29 c	56.20 e	56.77 abc
V_8	112.43 b	64.96 d	64.87 d	52.23 bcd
V_9	133.79 a	63.45 de	87.90 a	62.33 a
V_{10}	117.51 b	71.45 bc	71.07 c	61.27 a
V_{11}	104.71 c	62.73 de	51.43 f	50.23 cde
V_{12}	103.01 cd	64.87 de	42.17 gh	38.20 f
V_{13}	101.91 cd	62.00 de	60.72 de	48.60 de
Lsd	6.38	3.43	4.57	7.79
CV%	3.53	3.07	4.56	9.56
Level of significance	*	*	*	*

In each column, the means followed by the same letters do not differ significantly according to Fisher's least significant difference test ($p \leq 0.05$).

4.3 Individual weight of fruit (g)

The individual weight of fruit was significantly influenced by different cultivars and it ranged from 157.5 to 385.03 g (Appendix I and Figure 1). The highest individual weight of fruit was recorded in Kheermohan (V_2, 385.03 g) which was about two times higher than the lowest one i.e. Golapbaas (V_3, 157.5 g). It was also observed that the highest individual weight of fruit of Kheermohan was statistically similar with Bhaaduria (V_9) (Figutre 1).

Individual weight of fruit is a varietal characteristic. In the present study, it was observed that the weight of individual fruit depends on the length and diameter of fruit. The fruit of Kheermohan had the highest weight because of its highest diameter and moderate length of fruit while Golapbaas gave lighter fruit due to its lowest length and diameter (Figure 1 and Table 2). Different studies in home and abroad also reported a wide range of variability of fruit weight among the mango cultivars (Souza *et al.*, 2018; Rasha *et al.*,

2016; Jilani *et al.*, 2010; Shafique *et al.*, 2006; Gowda and Huddar, 2001 and Bhuyan and Islam, 1986).

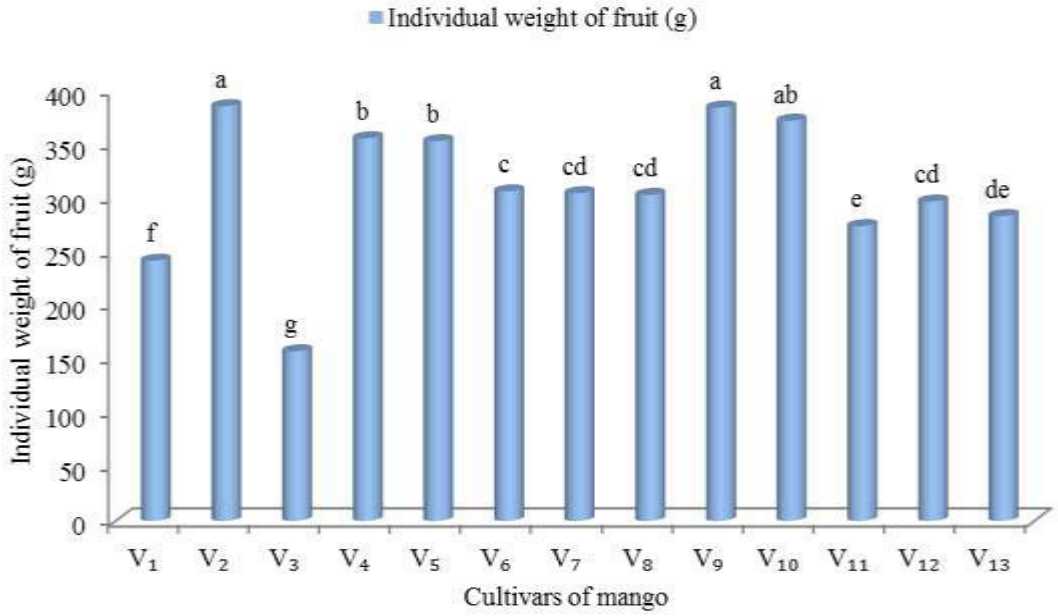

Fig. 1: Individual weight of indigenous cultivars of mango

4.4 Weight of pericarp (g)

A significant variation was observed among the indigenous cultivars of mango in respect of weight of pericarp (Appendix II). The weight of pericarp ranged from 38.93 to 87.90 g and the maximum weight of pericarp was recorded in Bhaaduria (V_9, 87.90 g) while the lowest was in Golapbaas (V_3, 38.93 g) and it was about two times lower than the superior (Table 2). However, the minimum pericarp weight of Golapbaas was statistically similar with Phunia (V_{12}) and Monmohan (V_1) (Table 2).

The weight of pericarp would possibly be affected by the length and diameter of individual fruit. In this study, Bhaaduria had the highest pericarp weight because of its highest length and moderate diameter while Golapbaas had the lowest one. Similar result was also reported by Rasha *et al.* (2016), Jilani *et al.* (2010) and Shafique *et al.* (2006) where they observed that the weight of pericarp was related to the length and diameter of individual fruit.

4.5 Weight of stone (g)

The weight of stone of mango cultivars ranged from 30.17 to 62.33 g and it varied significantly among the cultivars (Table 2 and Appendix II). The largest stone weight

was found in Bhaaduria (V_9, 62.33 g) which was statistically similar with Koitori (V_{10}, 61.27 g) while the minimum weight was recorded in Golapbaas (V_3, 30.17 g). It was also observed that Golapbaas was about 2 times smaller than Bhaaduria in respect of weight of stone.

In the present experiment, the weight of stone is a varietal characteristic and it differed among the different cultivars. The maximum weight of stone was found in Bhaaduria and Koitori possibly because of their being the largest of all other mangoes. Rasha *et al.* (2016), Jilani *et al.* (2010) and Shafique *et al.* (2006) also concluded that weight of stone differed among the different cultivars of mango.

4.6 Weight of pulp (g)

A significant variation was observed among the cultivars of mango in respect of weight of pulp (Appendix II). However, the weight of pulp of different mango cultivars ranged from 88.40 to 256.10 g and the maximum weight of pulp was recorded in Haaji (V_5, 256.10 g) and the lowest was in Golapbaas (V_3, 88.40 g) (Table 3). It was also observed that the maximum weight of pulp of Haaji was statistically similar with Kheermohan (V_2).

Weight of pulp depends on fruit weight as well as stone weight of fruit of different cultivars. In general, the fruit having larger stone have comparatively lower portion of pulp. In this study, variation on weight of pulp was observed and Haaji produced the highest weight of pulp due to its comparatively minimum weight of stone (Table 3). Similar results were also reported by Rasha *et al.* (2016), Jilani *et al.* (2010), Shafique *et al.* (2006) and Rajput *et al.* (1999) where the weight of pulp differed among the mango cultivars.

4.7 Fruit pulp and stone ratio (wt. basis)

Fruit pulp and stone ratio was significantly influenced by different indigenous cultivars of mango and ranged from 2.94 to 5.81 (Appendix II and Table 3). The highest pulp and stone ratio was found in Lakhno (V_4, 5.81) which was about 1.5 times more than the lowest one in Golapbaas (V_3, 2.94). The highest pulp and stone ratio of Lakhno was statistically identical to Phunia (V_{12}).

Pulp and stone ratio is an important quality parameter. The mango cultivar having higher pulp and stone ratio is considered as a better quality attribute. From the present study, it

was observed that Lakhno had the highest pulp and stone ratio because of its lower weight of stone. Bhuyan and Islam (1986) also reported that pulp and stone ratio varied greatly among the cultivars.

Table 3: Weight of pulp (g), pulp and stone ratio (wt. basis), firmness (kg/cm^2) and shelf-life (days) of mango cultivars

Cultivar	Weight of Pulp (g)	Pulp and stone ratio (wt. basis)	Firmness (kg/cm^2)	Shelf-life (days)
V_1	163.67 h	4.65 bc	1.76 fgh	6.67 ef
V_2	251.13 ab	4.22 bcd	1.96 ef	7.33 def
V_3	88.40 i	2.94 f	1.53 h	7.67 de
V_4	234.00 c	5.81 a	1.78 fg	9.33 bc
V_5	256.10 a	4.87 b	1.65 gh	8.33 cd
V_6	201.33 e	4.74 b	3.26 a	8.33 cd
V_7	191.33 ef	3.43 ef	3.40 a	10.00 ab
V_8	185.60 fg	3.56 def	2.63 b	10.67 a
V_9	233.47 c	3.79 de	2.34 cd	6.33 f
V_{10}	239.26 bc	3.92 cde	2.54 bc	8.33 cd
V_{11}	172.03 gh	3.44 ef	2.30 d	7.33 def
V_{12}	216.20 d	5.69 a	2.17 de	9.00 bc
V_{13}	173.93 gh	3.59 def	2.05 e	6.67 ef
Lsd	14.70	0.77	0.24	1.11
CV%	4.37	10.91	6.26	8.14
Level of significance	*	*	*	*

In each column, the means followed by the same letters do not differ significantly according to Fisher's least significant difference test ($p \leq 0.05$).

4.8 Firmness (kg/cm^2)

The firmness of mango fruit was measured externally at the central part of the fruits and has been presented in Table 3. The present study demonstrated significant variation in firmness among the cultivars of mango which ranged from 1.53 to 3.40 kg/cm^2 (Appendix III and Table 3). The highest value of firmness was recorded in Kalibhog (V_7, 3.40 kg/cm^2), whereas the lowest value was recorded in Golapbaas (V_3, 1.53 kg/cm^2) and this value was about more than two times lower than the superior. The highest firmness of Kalibhog was statistically similar with Sonamohan (V_6) and lowest firmness of Golapbaas was statistically identical to Haaji (V_5).

Firmness is one of the most common physical parameters used to assess the texture and freshness of a fruit. From the results of present study, it was observed that the firmness value varied among the cultivars. It would most possibly be due to their different texture

of pericarp. However, the present study showed that Kalibhog was firmer than the other cultivars. Similar variation of firmness in mango cultivars was also reported earlier by some authors (Vásquez-Caicedo *et al.*, 2002; Gowda and Huddar, 2001; Aina and Oladunjoye, 1993 and Lee *et al.*, 1988).

4.9 Shelf-life of fruits (days)

The data on shelf-life of mango fruits have been presented in Table 3, where it ranged from 10.67 to 6.33 days. The result showed significant differences among the cultivars of mango with respect to the shelf-life (Appendix III). It was observed that Madhuchuski (V_8) had the highest shelf-life (10.67 days) compared to other cultivars and Bhaaduria (V_9) had the lowest shelf-life (6.33 days) which was about more than 1.5 times lower than Madhuchuski (Table 3). However the highest shelf-life of Madhuchuski was statistically similar with Kalibhog (V_7, 10 days) and the lowest shelf-life of Bhaaduria was statistically similar with both Monmohan (V_1) and Belbhog (V_{13}, 6.67 days).

The shelf-life of mango fruit is an important quality trait and the cultivar having long shelf-life is desirable for storing long period of time and/or for long supply chain. The present study showed that both Madhuchuski and Kalibhog had better shelf-life than other cultivars; hence, these two varieties could be selected for long distant market as well as for export market. A number of studies showed that the shelf-life of mango varied among the cultivars as well as storage condition and treatment (Hossain *et al.*, 2014; Islam *et al.*, 2013; Reddy and Haripriya, 2002; Osthuyes *et al.*, 2000 and Thangaraj and Irulappan, 1988).

4.10 Pericarp colour of mango cultivars

In the present study, colour values of pericarp of indigenous mangoes were measured at ripening stage and presented as lightness (L), chroma (C*) and hue angle (H°). A significant variation in L values was observed among the indigenous cultivars of mango, where the highest L value (65.67) was detected in Belbhog (V_{13}) which was statistically identical to Sonamohan (V_6) and Lakhno (V_4), respectively. On the contrary, the lowest value of L (24.25) was measured in Golapbaas (V_3) (Appendix IV and Table 4). The lowest value of L indicates lighter in colour whereas the higher value of L indicates darker in colour. Similar as L, the chroma values of mangoes also differed significantly among the cultivars (Appendix IV). The highest C* value (57.35) was detected in Lakhno (V_4) while the lowest C* value (19.76) in Golapbaas (V_3) (Table 4). These

results indicate that highest chroma value of pericarp of Lakhno had more intense yellow colour and the lowest chroma value in Golapbaas indicates less intense yellow colour of pericarp. Regarding hue angle (H°), these values also differed significantly and it ranged from -68.86 to 87.07 among the mango cultivars where the highest value (87.07) was recorded in Haaji (V_5) and the lowest value (-68.86) was in Kheermohan (V_2) (Appendix IV and Table 4).

Fruit colour is an important maturation indicator for fruit harvest and the colour differs considerably among cultivars. Monmohan (V_1), Lakhno (V_4), Haaji (V_5), Sonamohan (V_6) and Koitori (V_{10}) were yellow in colour with a varying intensity of colour, while Kheermohan (V_2), Golapbaas (V_3), Kalibhog (V_7), Madhuchuski (V_8), Bhaaduria (V_9) and Kuapahari (V_{11}) were greenish in colour, respectively (Plate 7). The present results are in accordance with Souza *et al*. (2018), Nguyen *et al.* (2004), Vásquez-Caicedo *et al.* (2002), Gowda and Huddar (2001), Lee *et al.* (1988) and Medlicott *et al.* (1986).

Table 4: Pericarp colour of mango cultivars

Cultivar	L	C*	H°
V_1	55.92 b	40.41 c	80.25 a
V_2	44.79 d	32.74 d	-68.86 b
V_3	24.25 e	19.76 f	-58.85 b
V_4	63.79 a	57.35 a	71.13 a
V_5	54.92 b	43.05 bc	87.07 a
V_6	65.28 a	43.74 b	28.54 ab
V_7	56.49 b	33.98 d	-25.08 ab
V_8	49.35 c	24.76 e	-23.23 ab
V_9	56.86 b	34.07 d	-25.05 ab
V_{10}	55.00 b	43.75 b	86.70 a
V_{11}	49.68 c	25.25 e	-23.70 ab
V_{12}	57.16 b	34.24 d	-25.06 ab
V_{13}	65.67 a	43.76 b	28.53 ab
Lsd	2.79	2.77	114.91
CV%	3.09	4.49	672.57
Level of significance	*	*	*

In each column, the means followed by the same letters do not differ significantly according to Fisher's least significant difference test ($p \leq 0.05$).

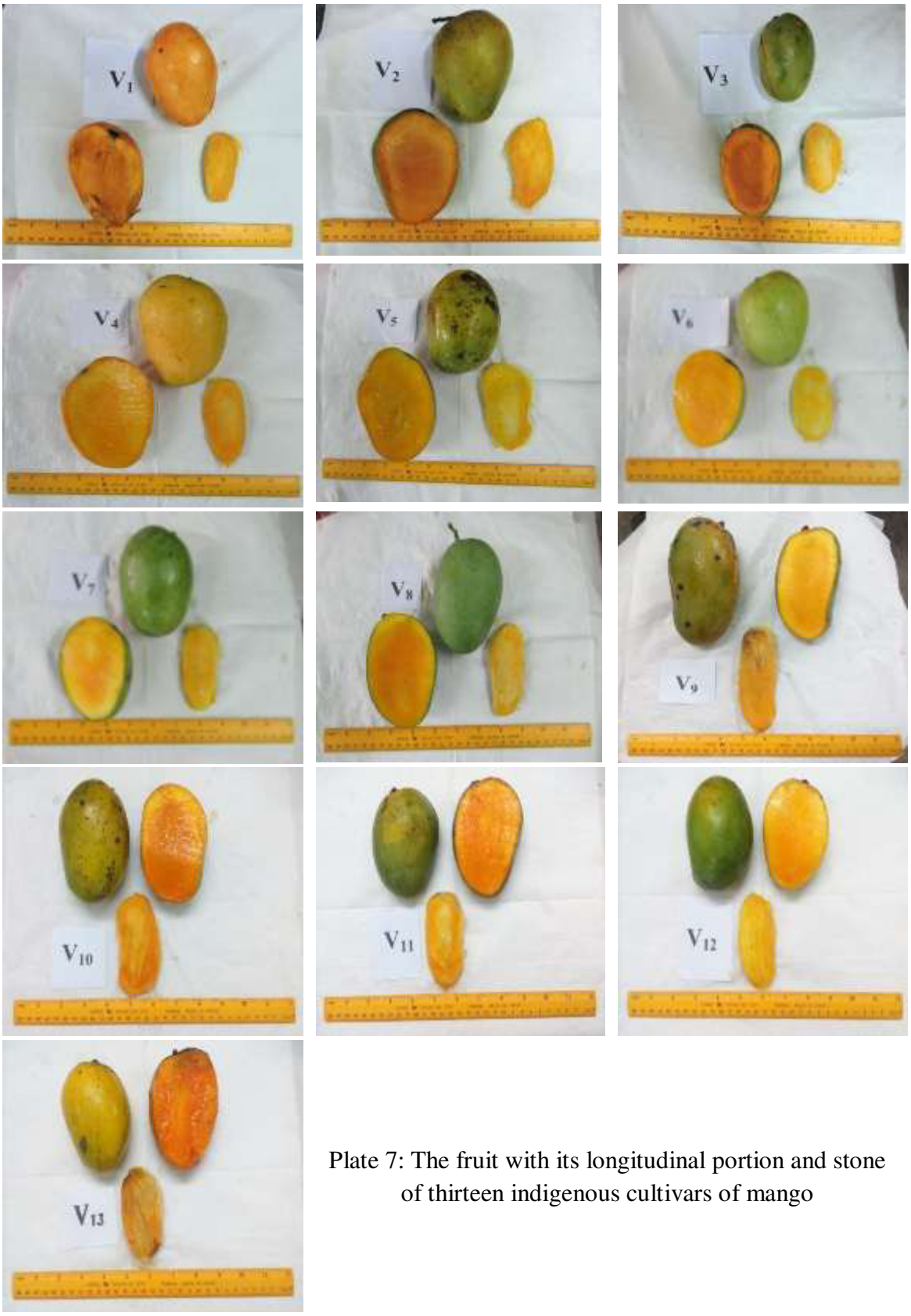

Plate 7: The fruit with its longitudinal portion and stone of thirteen indigenous cultivars of mango

4.11 Pulp colour of mango cultivars

The results of the present experiment indicated that the lightness value (L) of pulp differed significantly among the cultivars of mango (Appendix V). The lowest value of L (44.24) was recorded in Haaji (V_5) which was statistically similar with Lakhno (V_4), Belbhog (V_{13}) and Golapbaas (V_3), respectively indicating the pulp of these mangoes darker in colour compared to others (Table 5). Whereas, the maximum value of L (61.46) was measured in Kalibhog (V_7) which was statistically identical with Kheermohan (V_2), Kuapahari (V_{11}), Koitori (V_{10}) and Madhuchuski (V8), respectively, indicating the pulp of these mangoes were lighter in colour (Table 5).

Table 5: Pulp colour of mango cultivars

Cultivar	L	C*	H°
V_1	55.70 bc	54.57 c	71.22 c
V_2	60.54 a	47.33 d	81.68 a
V_3	49.59 d	41.59 e	69.57 cd
V_4	48.97 d	48.72 d	73.47 b
V_5	44.24 e	42.22 e	73.22 b
V_6	53.86 c	57.19 bc	68.64 d
V_7	61.46 a	56.90 bc	73.18 b
V_8	58.94 ab	64.96 a	68.72 d
V_9	53.19 c	57.53 b	73.48 b
V_{10}	59.28 a	65.61 a	68.86 d
V_{11}	59.88 a	47.46 d	81.24 a
V_{12}	53.79 c	57.54 b	73.41 b
V_{13}	49.58 d	41.49 e	70.03 cd
Lsd	3.25	2.72	1.96
CV%	3.55	3.08	1.60
Level of significance	*	*	*

In each column, the means followed by the same letters do not differ significantly according to Fisher's least significant difference test ($p \leq 0.05$).

Regarding chroma value (C*), it also differed significantly and the highest value of C* (65.61) was recorded in Koitori (V_{10}) which was statistically similar with Madhuchuski (V_8) indicating that the pulp of these fruits were more intense in colour compared to the pulp of other cultivars (Table 5). On the other hand, the lowest value of C* (41.49) was recorded in Belbhog which was statistically identical to Golapbaas and Haaji, respectively indicating less intense colour of pulp. Similar as L and C* value, hue angle (H°) value of pulp of mangoes also varied significantly among the cultivars of mango

(Appendix V). The highest value of H° (81.68) was measured in both Kheermohan (V_2) and Kuapahari (V_{11}) indicating the colour of the pulp of these fruits was red in colour. On the contrary, the lowest value of H° (68.64) was detected in Sonamohan (V_6) which was statistically identical to Koitori (V_{10}) and Madhuchuski (V_8), respectively indicating the pulp of these mangoes were yellowish in colour (Plate 7). Similar variations in pulp colour of mangoes were also reported earlier by Souza *et al.* (2018), Vásquez-Caicedo *et al.* (2002), Gowda and Huddar (2001) and Lee *et al.* (1988).

4.12 Total Soluble Solids (% Brix)

In the present study, significant differences in the TSS were found in mango cultivars which ranged from 13.0 to 27.33% (Appendix VI and Table 6). The highest TSS was recorded in Bhaaduria (V_9, 27.33%) and the lowest was in three cultivars i.e. Golapbaas (V_3), Lakhno (V_4) and Sonamohan (V_6, 13.0%). It was also observed that Bhaaduria contained about 2 times higher amount of TSS than Golapbaas, Lakhno and Sonamohan cultivars of mango, respectively.

Fruit TSS is an important biochemical attribute. The cultivar having higher TSS is considered as a superior cultivar compared to other cultivars having lower TSS. In this study, it was observed that TSS value varied significantly among the mango cultivars and Bhaaduria had the highest value of TSS. Similar variations in TSS among the different cultivars of mango were also observed by different authors (Souza *et al*., 2018; Rasha *et al.*, 2016; Islam *et al*., 2013; Shafique *et al.*, 2006; Vásquez-Caicedo *et al.*, 2002; Gowda and Huddar, 2001; Rajput *et al.*, 1999; Singh *et al.*, 1998; Ahmed, 1994; Lianni *et al*., 1994 and Absar *et al.*, 1993).

4.13 Pulp pH

A significant variation in pH values was observed among the cultivars of mango which ranged from 5.29 to 6.41 (Appendix VI and Table 6). The highest pH value was found in Kuapahari (V_{11}, 6.41) while the lowest value was in Sonamohan (V_6, 5.29). The highest pH value of Kuapahari was statistically similar with Phunia (V_{12}), Koitori (V_{10}) and Belbhog (V_{13}) and the lowest value of Sonamohan was statistically identical to Madhuchuski (V_8). The higher value of pH was obviously due to lowering of acidity which indicates the sourness of taste.

In the present study, variation in pulp pH was recorded among the mango cultivars and this result is in agreement with Islam *et al.* (2013), Shafique *et al.* (2006), Zhu *et al.*

(2002), Vásquez-Caicedo *et al.* (2002), Gowda and Huddar (2001), Salles and Tavares (1999), Joshi (1998), Shahjahan *et al.* (1994) and Kumar *et al.* (1993) where they observed that pH of mango pulp was differed among the cultivars during various stages of ripening.

Table 6: TSS (% Brix), pulp pH and concentration of vitamin C (mg/100 g fw) among the mango cultivars

Cultivar	TSS (% Brix)	Pulp pH	Vitamin C (mg/100 g fw)
V_1	19.33 c	5.78 d	35.66 cd
V_2	16.00 d	5.74 de	32.25 de
V_3	13.00 f	5.96 cd	27.90 e
V_4	13.00 f	6.12 bc	34.53 d
V_5	14.33 ef	6.16 bc	45.89 b
V_6	13.00 f	5.29 f	28.66 e
V_7	15.33 de	6.09 bc	27.90 e
V_8	18.67 c	5.52 ef	41.16 bc
V_9	27.33 a	6.12 bc	46.08 b
V_{10}	23.00 b	6.27 ab	43.24 b
V_{11}	21.67 b	6.41 a	65.97 a
V_{12}	16.00 d	6.31 ab	32.07 de
V_{13}	22.33 b	6.24 ab	45.51 b
Lsd	1.50	0.24	5.68
CV%	4.96	2.36	8.68
Level of significance	*	*	*

In each column, the means followed by the same letters do not differ significantly according to Fisher's least significant difference test ($p \leq 0.05$).

4.14 Vitamin C content (mg/100g fw)

Vitamin C is considered to be an important quality parameter of mango fruit. Significant variation in vitamin C was measured among the cultivars of mango which ranged from 28.66 to 65.97 mg/100 g fw (Appendix VI and Table 6). The highest amount of vitamin C was detected in Kuapahari (V_{11}, 65.97 mg/100 g fw) and the lowest concentration of vitamin C was measured from both Golapbaas (V_3, 27.90 mg/100 g fw) and Kalibhog (V_7, 27.90 mg/100 g fw) which was statistically similar with Sonamohan (V_6, 28.66 mg/100 g fw) (Table 6).

Vitamin C is a powerful antioxidant and a high vitamin C concentration in mango fruit is a desirable quality trait. However, the variation in vitamin C content depends on the variation of mango cultivars. The present study showed that Kuapahari contained

significantly two times higher amount of vitamin C than the other cultivars (Table 6). Ara *et al.* (2014), Jilani *et al.* (2010), Shafique *et al.* (2006), Gowda and Huddar (2001), Rajput *et al.* (1999), Gafur *et al.* (1994), Shahjahan *et al.* (1994), Absar *et al.* (1993), Laborem *et al.* (1992) and Malek *et al.* (1966) also found variation in the concentration of vitamin C contents among the mango varieties.

4.15 Reducing sugar content (mg/100 g fw)

Content of reducing sugar varied from 5.41 to 18.09 mg/100 g fw and it differed significantly among the mango cultivars (Figure 2 and Appendix VII). The result revealed that the content of reducing sugar was highest in Golapbaas (V_3, 18.09 mg/100 g fw) which was statistically similar with Bhaaduria (V_9, 18.04 mg/100 g fw) and the lowest content was in Monmohan (V_1, 5.41 mg/100 g fw) which indicates that Monmohan had more than 3 times lower content of reducing sugar than the superior.

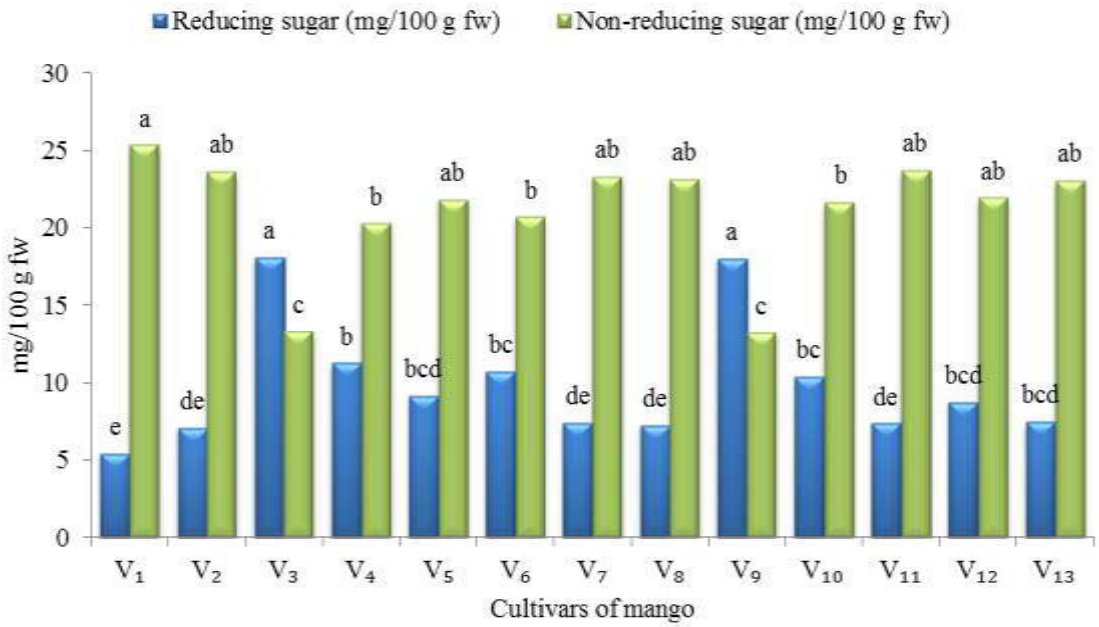

Fig. 2: Reducing and non-reducing sugar content of indigenous cultivars of mango

The differences of reducing sugars would most possibly be due to their varietal characteristics. Similar variation of reducing sugar was also found in different mango cultivars in some observational studies by Souza *et al.* (2018), Islam *et al.* (2013), Rangavalli *et al.* (1993), Castro *et al.* (1992), Tripathi (1988), Upadhyay and Tripathi (1985) and Tandon *et al.* (1985).

4.16 Non-reducing sugar content (mg/100 g fw)

The present study demonstrated significant variation in non-reducing sugar content among the cultivars of mango which ranged from 13.25 to 25.34 mg/100 g fw (Appendix VII and Figure 2). The highest amount of non-reducing sugar was recorded in Monmohan (V_1, 25.34 mg/100 g fw) whereas the lowest one in Bhaaduria (V_9, 13.25 mg/100 g fw) which was statistically similar with Golapbaas (V_3, 13.31 mg/100 g fw). It was also observed that Monmohan was also statistically identical to Kuapahari (V_{11}), Kheermohan (V_2), Kalibhog (V_7), Madhuchuski (V_8), Belbhog (V_{13}), Phunia (V_{12}) and Haaji (V_5) for their higher non-reducing sugar content and the highest amount was about 2 times higher than the lowest one.

Non-reducing sugar content was significantly varied due to the physico-chemical characteristics among the mango cultivars in this study. Similar results were also detected in some studies by Islam *et al*. (2013), Rangavalli *et al.* (1993), Joshi and Roy (1988) and Sarkar and Mushi (1978). The results of the present study also indicated that the cultivar having higher amount of non-reducing sugar contained lower amount of reducing sugar.

4.17 Beta-carotene content (mg/100 g fw)

In the present study, beta-carotene content was significantly influenced by the different cultivars of mango and ranged from 3.37 to 7.14 mg/100 g fw (Appendix VII and Table 7). The highest concentration of β-carotene was detected in Madhuchuski (V_8, 7.14 mg/100 g fw) which was about 2 times more than the lowest one in Haaji (V_5, 3.37 mg/100 g fw). The highest β-carotene content of Madhuchuski was statistically identical to Koitori (V_{10}), Kalibhog (V_7) and Kheermohan (V_2) while the lowest β-carotene content of Haaji was statistically similar with Monmohan (V_1).

Beta carotene is the precursor of vitamin A and it is an important quality parameter. The cultivar having higher vitamin A content is considered as a superior cultivar. However, it was observed that Madhuchuski had the highest β-carotene content among the mango cultivars because of their varietal characteristics. These findings are in accordance with previous reports that β-carotene content varied from cultivars to cultivars (Vásquez-Caicedo *et al.*, 2002).

Table 7: Beta-carotene (mg/100 g fw) and total polyphenols (mg GAE/100 g fw) content among the mango cultivars

Cultivar	β-carotene (mg/100 g fw)	Total polyphenols (mg GAE/100 g fw)
V_1	4.15 cd	86.65 abc
V_2	6.23 ab	90.19 abc
V_3	4.37 bcd	74.46 c
V_4	4.69 bcd	89.78 abc
V_5	3.37 d	76.82 c
V_6	4.90 bcd	95.12 abc
V_7	6.32 ab	78.76 bc
V_8	7.14 a	98.97 ab
V_9	5.75 abc	104.46 a
V_{10}	6.34 ab	97.88 ab
V_{11}	5.89 abc	81.55 bc
V_{12}	4.43 bcd	81.59 bc
V_{13}	4.37 bcd	102.42 a
Lsd	2.02	20.82
CV%	22.86	13.92
Level of significance	*	*

In each column, the means followed by the same letters do not differ significantly according to Fisher's least significant difference test ($p \leq 0.05$).

4.18 Total polyphenol content (mg GAE/100 g fw)

The total polyphenol content of thirteen selected indigenous mango fruit have been shown in Table 7. Among the cultivars studied, the total polyphenol content of mango ranged from 74.46 to 104.46 mg GAE/100 g fw (Table 7). The maximum concentration of total polyphenol of mango was detected in Bhaaduria (V_9, 104.46 mg GAE/100 g fw) and the minimum in Golapbaas (V_3, 74.46 mg GAE/100 g fw). The result showed significant differences among the cultivars of mango with respect to the phenolics whereas Bhaaduria cultivar showed about 1.5 times comparatively higher phenolics content than the other cultivars (Appendix VII and Table 7). However, the maximum concentration of total polyphenol in Bhaaduria was statistically similar with Belbhog (V_{13}), Madhuchuski (V_8) and Koitori (V_{10}). It was also found that the minimum concentration of total polyphenol in Golapbaas was statistically similar with Haaji (V_5), Kalibhog (V_7), Kuapahari (V_{11}) and Phunia (V_{12}).

Total polyphenols are strong antioxidant and it is an important quality attribute of a mango cultivar. Present study showed that Bhaaduria had highest phenol content due to

their varietal characteristics. Souza *et al*. (2018) and Vásquez-Caicedo *et al.* (2002) also concluded the same results in respect of polyphenols among the mango cultivars. The variation in total polyphenol content of mango cultivars would also most possibly be due to β-carotene content among them. Bhaaduria had maximum total polyphenol content due to its moderately higher β-carotene content while Golapbaas gave minimum polyphenol content due to its moderately lower β-carotene content (Table 7).

CHAPTER 5

SUMMARY AND CONCLUSION

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Present lab-based study examined physico-chemical characteristics of thirteen indigenous cultivars of mango collected from Chapai Nawabganj district. A single factor experiment was conducted in Completely Randomized Design (CRD) with five replications during the period from June, 2017 to July 2017 in the laboratory of Horticulture and laboratory of Food Processing and Preservation of HSTU, Dinajpur. Observations were made on length of fruit, diameter of fruit, individual weight of fruit, weight of pericarp, weight of pulp, weight of stone, pulp and stone ratio, pericarp and pulp colour of fruit, firmness, total soluble solids, pulp pH, vitamin C, sugar, total polyphenols and beta-carotene. Data were recorded carefully and analyzed statistically and interpreted. Different physical and chemical attributes were compared where most of the mean sums of square for all parameter were found significant.

Findings of the present experiment indicated that Bhaaduria (133.79 cm) had the longest fruit whereas Golapbaas (84.57 cm) produced the shortest fruit. Kheermohan (76.51 cm) had the highest diameter which was statistically similar with Lakhno while the lowest diameter was in Golapbaas (54.73 cm). In respect of individual weight of fruit, the highest value was recorded in Kheermohan (385.03 g) and the lowest one in Golapbaas (157.5 g). It was observed that the weight of pericarp was maximum in Bhaaduria (87.90 g) while the minimum was in Golapbaas (38.93 g). It was further observed that the largest stone weight was detected in Bhaaduria (62.33 g) which was statistically similar with Koitori (61.27 g) while the minimum weight was recorded in Golapbaas (30.17 g). Present experiment also showed that Haaji (256.10 g) gave the highest pulp weight due to its comparatively minimum weight of stone and statistically similar with Kheermohan. The lowest pulp weight was in Golapbaas (88.40 g). It was calculated that Lakhno (5.81) had the highest pulp and stone ratio because of its lower weight of stone which was statistically similar with Phunia while Golapbaas (2.94) had the lowest one.

In the present study, pericarp colour of mango fruits varied significantly among the cultivars where Monmohan, Lakhno, Haaji, Sonamohan and Koitori were yellow in colour with a varying intensity of colour, while Kheermohan, Golapbaas, Kalibhog, Madhuchuski, Bhaaduria and Kuapahari were greenish in colour, respectively. Regarding pulp colours, both Kheermohan and Kuapahari were red in colour while the

pulp of Sonamohan was yellowish in colour which was statistically identical to Koitori and Madhuchuski, respectively. Considering firmness, the highest value of firmness was recorded in Kalibhog (3.40 kg/cm^2), whereas the lowest value was recorded in Golapbaas (1.53 kg/cm^2). The highest firmness of Kalibhog was statistically similar with Sonamohan and the lowest firmness of Golapbaas was statistically identical to Haaji. It indicates that Kalibhog was firmer than the other cultivars because of their different texture of pericarp. The present study also showed that Madhuchuski had the highest shelf-life (10.67 days) which was statistically similar with Kalibhog (10 days) compared to other cultivars and Bhaaduria had the lowest shelf-life (6.33 days) which was statistically similar with both Monmohan and Belbhog (6.67 days).

Considering the biochemical traits, it is revealed that the level of TSS was comparatively lower (13.0 %) in three cultivars *viz*. Golapbaas, Lakhno and Sonamohan than the other cultivars while the highest value (27.33 %) was in Bhaaduria. With respect to the pulp pH value, Kuapahari showed the highest pH value (6.41) most possibly due to lowering of acidity and indicates sourness of taste while the lowest value was in Sonamohan (5.29). The highest pH value of Kuapahari was statistically similar with Phunia, Koitori and Belbhog and the lowest value of Sonamohan was statistically similar with Madhuchuski. The present study showed that Kuapahari contained significantly highest amount of vitamin C (65.97 mg/100 g fw) and the lowest concentration of vitamin C was measured from both Golapbaas and Kalibhog (27.90 mg/100 g fw) which was statistically similar with Sonamohan (28.66 mg/100 g fw). It is also observed that the content of reducing sugar was highest in Golapbaas (18.09 mg/100 g fw) which was statistically similar with Bhaaduria (18.04 mg/100 g fw) and the lowest content was in Monmohan (5.41 mg/100 g fw). On the other hand, the highest amount of non-reducing sugar was recorded in Monmohan (25.34 mg/100 g fw) and it was statistically similar with Kuapahari, Kheermohan, Kalibhog, Madhuchuski, Belbhog, Phunia and Haaji whereas the lowest in Bhaaduria (13.25 mg/100 g fw) which was statistically similar with Golapbaas (13.31 mg/100 g fw). Regarding β-carotene content of the mango cultivars, the highest concentration of β-carotene was detected in Madhuchuski (7.14 mg/100 g fw) which was statistically similar with Koitori, Kalibhog and Kheermohan while the lowest β-carotene content of Haaji (3.37 mg/100 g fw) was statistically similar with Monmohan. In respect of the total polyphenol content of mango, Bhaaduria showed the maximum phenol content (104.46 mg GAE/100 g fw) which was statistically similar

with Belbhog, Madhuchuski and Koitori and the minimum in Golapbaas (74.46 mg GAE/100 g fw), was statistically similar with Haaji, Kalibhog, Kuapahari and Phunia. The variation in total polyphenol content of mango cultivars would most probably be due to β-carotene content among them.

Considering the physical and biochemical characteristics of the 13 indigenous mango cultivars, Bhaaduria was found to be superior in respect of individual weight of fruit, TSS, β-carotene, total polyphenols, vitamin C and sugars. But due to short shelf-life, Bhaaduria could be used in the promotion for fresh consumption. Regarding yield contributing characters (individual fruit weight, diameter, pulp weight), Kheermohan could be a good cultivar from economic point of view. Although individual fruit weight, TSS and vitamin C were not so high but considering shelf-life and antioxidants (total polyphenols and β-carotene), Madhuchuski could be considered as a good cultivar too. Therefore, overall physicochemical characteristics, these three cultivars (Bhaaduria, Kheermohan and Madhuchuski) were found promising in region of Chapai Nawabganj in terms of fruit traits. These results of the study may help in selecting mango cultivar for fresh consumption, processing industry and varietal development programme. In order to validate the findings of this research, further trial will be needed. As a follow-up to this current research, varietal trial in different agro-climate region of the country may be considered for further studies.

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APPENDICES

APPENDICES

Appendix I: Analysis of variance (mean square) of the data for length of fruit, diameter of fruit and individual weight of fruit of mango cultivars

Source of variation	df	Length of fruit	Diameter of fruit	Weight of fruit
Treatments	12	484.86*	107.21*	12238.9*
Error	52	14.44	4.17	162.52
Total	64			

*= Significant at 5% level of probability

Appendix II: Analysis of variance (mean square) of the data for weight of pericarp, weight of stone, weight of pulp and pulp and stone ratio of mango cultivars

Source of variation	df	Weight of pericarp	Weight of stone	Weight of pulp	Pulp and stone ratio
Treatments	12	744.87*	323.61*	6339.87*	2.38*
Error	52	7.41	21.56	76.75	0.21
Total	64				

*= Significant at 5% level of probability

Appendix III: Analysis of variance (mean square) of the data for firmness and shelf-life of mango cultivars

Source of variation	df	Firmness	Shelf-life
Treatments	12	1.01*	5.31*
Error	52	0.02	0.44
Total	64		

*= Significant at 5% level of probability

Appendix IV: Analysis of variance (mean square) of the data for pericarp colour of mango cultivars

Source of variation	df	L	C*	H°
Treatments	12	349.60*	306.64*	95.17*
Error	52	2.76	2.71	4687.86
Total	64			

*= Significant at 5% level of probability

Appendix V: Analysis of variance (mean square) of the data for pulp colour of mango cultivars

Source of variation	df	L	C*	H°
Treatments	12	86.17*	208.99*	55.43*
Error	52	3.75	2.62	1.36
Total	64			

*= Significant at 5% level of probability

Appendix VI: Analysis of variance (mean square) of the data for TSS, pulp pH and vitamin C of mango cultivars

Source of variation	df	TSS	Pulp pH	Vitamin C
Treatments	12	62.51*	0.33*	342.02*
Error	52	0.79	0.02	11.46
Total	64			

*= Significant at 5% level of probability

Appendix VII: Analysis of variance (mean square) of the data for reducing sugar, non-reducing sugar, β-carotene content and total polyphenol content of mango cultivars

Source of variation	df	Reducing sugar	Non-reducing sugar	β-carotene	Total polyphenols
Treatments	12	47.80*	42.19*	3.73*	304.35*
Error	52	5.16	4.57	1.43	153.89
Total	64				

*= Significant at 5% level of probability