# A STUDY ON THE PHYSICO-CHEMICAL PROPERTIES OF BANANA POWDER DURING STORAGE

**A THESIS**
**BY**

MD. MURTUZA KAMAL
Student No.: 1205042
Session: 2012-13
Semester: January – June, 2013

**MASTER OF SCIENCE (MS)**
**IN**
**FOOD PROCESSING AND PRESERVATION**

**DEPARTMENT OF FOOD PROCESSING AND PRESERVATION**
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY
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***In partial fulfillment of the requirements for the degree of***

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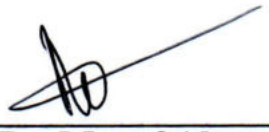

**(Dr. Maruf Ahmed )**
**Chairman of the Examination Committee**
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DEDICATED TO
MY
BELOVED PARENTS

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***The Author***

# ABSTRACT

The study was conducted to prepare banana powder from ripe banana and also to determine physico-chemical properties of banana powder during storage. Fresh ripe banana was analyzed for its composition. The banana pulp contained 70.75g moisture, 0.97g protein, 0.43g fat, 0.85g ash, 27g total carbohydrate, 135.72 mg potassium, 13.37 mg calcium, 31.46 mg magnesium, 0.178 mg zinc, 0.491 mg iron and 25.34 mg phosphorus per 100g. The sliced (approx. 2 mm thick) banana were pretreated (The first control sample was without treatment; the $2^{nd}$, $3^{rd}$ and $4^{th}$ sample were pretreated with 0.5% of citric acid, 0.1% of potassium metabisulfite (KMS) and mixed solution of 0.5% of citric acid with 0.1% of potassium metabisulfite (KMS) respectively for 10 minutes each), dried (at $60^0$ C for 24 hours), grounded into powder, packed (in 0.0508 mm thick polyethylene bags), stored at room temperature ($21^0$C- $32^0$C) and analyzed for physico-chemical properties during 180 day's storage at each & after 60 day's interval and all were mean values of each sample obtained each interval at the end of total storage period. During storage $4^{th}$ sample secured highest water holding capacity (3.678g/g) and oil holding capacity (0.985 g/g). Control sample secured the highest (8.915 %) & $4^{th}$ sample secured the lowest (6.117 %) moisture content. For ash content control sample secured highest (3.57 %) & $4^{th}$ sample the lowest (2.548 %) value. The protein content was highest in $4^{th}$ (3.01 %) & lowest in control sample (2.095 %). $4^{th}$ sample secured the highest (0.6625 %) & control the lowest (0.525 %) fat content. The total carbohydrate content of $4^{th}$ sample was highest (87.67 %). The analysis of mineral composition was showed that $4^{th}$ sample secured the highest potassium content (325.2 mg), calcium content (58.31 mg), magnesium content (148.4 mg), zinc content (2.653 mg), iron content (10.62 mg) & phosphorus content (78.22 mg) per 100g respectively. From the overall assessment $4^{th}$ sample was the best quality of banana powder which was pretreated with the mixed solution of 0.5% of citric acid with 0.1% of potassium metabisulfite (KMS).

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# CHAPTER I
# INTRODUCTION

# CHAPTER I

# INTRODUCTION

The generic name Musa is derived from the Arabic word "*mouz*". Bananas were known to the Early Arabs and appear in the Holy Koran as the "Tree of Paradise". The earliest 'scientific' classification of bananas was made by Linnaeus in 1783. He gave the name *Musa sapientium* to all dessert bananas which are sweet when ripe and which are eaten fresh.

The word "banana" is a general term embracing a number of species or hybrids in the *Musa* of the family *Musaceae.* Bananas and plantains (cultivars of banana having firmer and starchier fruit) are grown today in every humid tropical region and constitute the second largest fruit crop following the citrus fruits of the world (Haque, 2008). Due to its perishable nature the banana cannot be preserved more than 7 days at room temperature (20°C) from the initiation of ripening (Farid, 2003). About one fifth of the harvested bananas is spoiled or rejected (Choo, 2007). In order to increase the utilization of culled banana, some researchers have suggested converting the green banana into flour and starch (Suntharalingam and Ravindran, 1993).

The name *Musa paradisiacal* was given to the plantain group, which are cooked and consumed while still starchy. However, it is now known that these two apparent species are not species at all but both refer to closely related inter specific triploid hybrids. They are general names and cannot be used to differentiate between bananas and plantains (Robinson, 1996).

Banana (*Musa spp.)* is one of the oldest fruits cultivated by man from pre historic times of the world. Its names "Adam's fig". Apple of "Paradise" and the botanical name *Musa Paradiaca* are for suggestive of its antiquity. Banana has been an important cultivated fruits and by further most important of the tropical fruits and by further most important of the tropical fruits (Naik, 1963). This is one of the superior fruits of Bangladesh with respect to popularity, availability, production and consumption (Haque, 1988).

Both acreage and production, it occupies the top most position among the different kinds of fruits of this country. A very good number of bananas are in cultivation in Bangladesh. These are known by different local names, namely Sagar, Sabri, Champa etc, which are not found in the world literature of banana. If some information's could be gathered

regarding all these varieties and these data could be geared up with banana cultivars of the world, the findings could be utilized in future for selection and breeding of high yielding varieties for Bangladesh as well as for other countries.

FAO (2004) data sources put the world production of plantains at about 60 million tons (FAO, 2004). In West Africa, plantain production increased at an average annual rate of between 2.3% to 2.6% (FAO, 2004). The level of production of plantains in Africa is comparable with other fruits like grapes (57 million tons); citrus (50 million tons) but much greater than most other important fruits like apples (21 million tons) and mangoes (13 million tons) (FAO, 2004). The higher production figures for plantains has been attributed to the cheaper methods of growing that require few labor inputs, little soil preparation and little weeding are needed once the plant has established vegetative cover, (FAO, 2004).

Bananas, a major global food staple, are the fourth most important food in the world, after rice, wheat, and maize (Banana—food and wealth, 2002 ). The term "banana" as used here includes plantain (Daniells, 2003).Plantains are just types of bananas that are commonly more starchy at ripeness. Bananas are eaten as ripe raw fruit or cooked as a staple food, green or ripe. Plantains are usually eaten cooked. However, the use of the terms differs among countries, indicating that care is needed in communications about bananas and interpretations of studies on "banana" and global "banana" production data (Daniells, 2003). Bananas and plantains have both been classified as fruits in global Food and Agriculture Organization (1996) and Food and Agriculture Organization Food Balance Sheets, although they are both eaten as cooked staple foods. This underestimates their use as staple foods and presents a particular challenge in the interpretation of global data on the production and consumption of these foods.

More than 400 million people in developing countries consume bananas as a staple food; 100 million of these people are in Africa (Banana—food and wealth, 2002). The greatest diversity of bananas is in Southeast Asia, including Papua New Guinea, where bananas are believed to have their origin (Banana-food and wealth, 2002; Daniells, 2003). This is reflected by a number of banana cultivars in the food-composition tables in that region: 8 Thai (Puwastien *et al., 1999*), 19 Malaysian (Siong, 1985), and 11 Philippine banana cultivar entries (Abdon, 1980). The two secondary centers of banana diversity in the world are West and Central Africa and the East African Highlands (INIBAP, 2002). In

Uganda, Burundi, and Rwanda, banana consumption is from 250 to 400 kg per person per year (3 to 11 bananas daily, depending on the size of the bananas) (Banana-food and wealth, 2002; Daniells, 2003; FAO, 1996).

The banana fruit has a limited shelf life, which makes processing necessary. There are modern techniques that include production of chips or crisps, drying and pureeing made from unripe bananas that are made by peeling, dicing and frying the fruit (Frison, 1998). Traditional methods of processing bananas are used in most countries, where unripe bananas are made into chips, dried and stored as a famine food. In Southern highlands of Tanzania, bananas are traditionally processed into flour, the product known as "Khenyangwa," which is has a longer shelf life and later on cooked into ugali.

Banana is a tropical fruit of great acceptance and an economically important fruit available throughout the year. It constitutes 42% of the total production of fruits in Bangladesh. Banana is unique due to its high calories and nutritive values. As compared to apple, it contains five times more vitamin A and iron, four times protein, three times phosphorus, twice the carbohydrate and the other vitamins and minerals (Gasster, 1963). Various products like banana chips, banana figs, flour, powder, jam confectionery, dehydrated slice etc. can also be prepared from banana.

But banana being a fragile, perishable fruit and cannot be preserved for longer time after harvesting. Bangladesh, therefore, annually losses a huge amount money every year due to shorter post harvest life of bananas. Post harvest fruits losses due to insect infection are a serious worldwide problem. Worldwide post harvest losses of fruit and vegetables losses are as high as 30 to 40% and even much higher in some developing countries.

Reducing post harvest losses is very important; ensuring that sufficient food, both in quantity and in quality is available to every inhabitant in our planet. Reduction of post-harvest losses reduces cost of production, trade and distribution, lowers the price for the consumer and increases the farmer's income. According to the International Conference on Nutrition (ICN) about 50% perishable fruits, vegetable and roots are lost due to lack of post harvest techniques, which translate into billions of dollars (International Atomic Energy Agency, 1982).

Fresh fruits are generally used in season, but all the year-round production can be maintained by the use of frozen, canned and dehydrated fruits, (Aylward F, 1999). Dried

fruits and vegetables have certain advantages over other preservation methods. They are lighter in weight than their corresponding fresh produce and, at the same time, they do not require refrigerated storage. Preservation of banana by means of refrigeration is not very common in Bangladesh and recently we are facing electricity shortage, so drying will be the better option in this situation. Banana is a nutritious food; therefore if it is possible to prepare banana powder then it will be available all the year round. Although banana powder can be used as a ingredient for value added products, post harvest loss during season could be reduced and farmers will get better payment for their produce.

Keeping the above considerations in mind, the present research work has been under taken to convert ripe banana in the form of banana powder.

The objectives of the proposed research work were:

i. Preparation of banana powder from ripe banana
ii. Analysis of chemical properties of ripe banana and physico-chemical properties of banana powder during storage.

# CHAPTER II

# REVIEW OF LITERATURE

CHAPTER II

# REVIEW OF LITERATURE

## 2.1 General

The quality of banana fruits and banana products are largely dependent on the varieties and various postharvest treatments which are principally applied to increase the storability of fruits and products. Although banana is an important fruit of the sub tropics and a few works on these aspects of banana have been done under Bangladesh condition. Some important findings relevant to the present investigation have been reviewed below-

Banana is one of the vegetable fruit that grow well in the tropics. Since then, development of high yield, short-time growth, disease resistant banana varieties by institutions of agriculture have increased the volume of banana at harvest. These bananas are mainly transported to urban areas, where they would be eaten as fruit vegetables. However, unavoidable delay in transport, poor post harvest technology and fluctuating market demand result in overripe and senescence of fruits prior to market delivery. Hence, large amount of banana post- harvest losses serve as impetus to the study on processing and application of mature green bananas with view to diversify utilization of the crop. (Daramola and Osanyinlusi, 2005).

Banana plants are monocotyledonous perennial and important crop in the tropical and Sub tropical world regions (Valmayor *et al.*, 2000), including dessert banana, plantain and cooking bananas. Traded plantain (*Musa paradisiaca* AAB) and other cooking bananas (Musa ABB) are almost entirely derived from the AA-BB hybridization of *Musa acuminate* (AA) and *Musa bulbisiana* (BB) (Robinson, 1996). Plantain and cooking bananas are very similar to unripe dessert bananas (*Musa cavendish* AAA) in exterior appearance, although often larger; the main differences in the former being that their flesh is starchy rather than sweet, they are used unripe and require cooking. Dessert bananas are consumed usually as ripe fruits; whereas ripe and unripe plantain fruits are usually consumed boiled or fried (Adeniji *et al.*, 2006).

Plantains are typical climacteric fruits in that they exhibit a well defined preclimateric phase after harvesting during which the fruit remains unripe, the basal respiration rate is low and ethylene production is almost undetectable. The respiratory climacteric

commences spontaneously and there is a rapid and well-defined rise in respiratory rate which is closely synchronized with evolution of ethylene, with chlorophyll breakdown in the peel and with starch to sugar conversion and tissue softening in the pulp (Marriot and Lancaster, 1983; Ogazi, 1996). The fruit usually harvested at its mature but unripe stage, ripens within two to seven days, thus making plantain a highly perishable crop, particularly in the overripe stage (Robinson, 1996). An unripened banana and the plantain have high starch and low sugar levels plus copious amounts of bitter-tasting latex. Starch is converted to sugar as the fruit ripens, so that bananas can eventually contain about 25% of total sugars. As the banana ripens, the latex is also decomposed. Plantain has the stinging, bitter latex, so the peel is removed with a knife and the pulp is soaked in salt water for 5–10 min prior to cooking. Bananas are harvested unripe and green, because they can ripen and spoil very rapidly (Daniells *et al.*, 2001).

**2.2 Origin of Banana**

Bananas originated from South East Asia, a region considered as the primary centre of diversification of the crop and where the earliest domestication has occurred (Simmonds, 1962). This is an area bordered on the west by India and on the east by Samoa, Fiji and other South Pacific islands (Simmonds, 1966). *Musa acuminate* is said to have originated from Malaysia, while the hardy *Musa balbsiana* originated from Indochina. The low land areas of West Africa contain the world's largest range of genetic diversity in plantains (Musa AAB) (Ortiz and Vuylsteke, 1994). Conversely in East Africa, bananas are highly evolved into an important zone of secondary genetic diversity for the East African highland bananas (Musa AAA) (Smale, 2006).

Plantain and cooking banana belong to the family Musaceae and the genus Musa, tree like perennial, 2-9in tall, with an underground rhizome. They can be differentiated by the number of fingers in the bunch, a characteristics used in naming the fruits in many parts of southern part of Nigeria (Ogazi,1980).The origin of cultivated plantain and banana is from two wild diploid species: *Musa acuminate* and *Musa balbisiana* which have the genome as AA and BB respectively (Falana,1997).

Plantain belongs to the genus Musa of the family musaceae. Nearly all edible plantain cultivar are derived from two wild species, *Musa acuminate* and *Musa balbisiana* (Robinson, 1996). These wild species are classified on the basis of the proportion of the

genetic constitution contributed by each parental source (Robinson, 1996). Plantain is a staple crop and an important dietary source of carbohydrate in Nigeria and in the humid tropical zones of Africa, Asia and South America (Robinson, 1996). Plantain is rich in vitamins A, C and B group as well as minerals such as calcium and iron (Marriott and Lancaster, 1983; Robinson, 1996). Plantain provides between 9% and 35% of the total calories in the diets of more than 14 million people in Sub sahara Africa (Robinson, 1996). The contributions of this staple starch crop to the food chains of this region cannot be overemphasized (Robinson, 1996).

### 2.3 Production (tonnes) of Banana in Bangladesh

**Table: 2.1 Production (tonnes) of Banana in Bangladesh**

| 2009 | 2010 | 2011 |
|---|---|---|
| 836,183.00 | 818,254.00 | 800,840 |

Source FAOSTAT, 2012

### 2.4 Maturity of Musa *spp.*

Plantain require about three months from the beginning of flowering until harvest. Multiple fruits are produced on a large bunch, weighing between 50-200kg (Ogazi, 1996). Within the bunch are clusters of double rows of fruit called "hands" and individual fruit called "fingers". (Ogazi, 1996).

Maturity standards for plantains are less precise than they are for bananas. Several different external and internal fruit characteristics can be used to determine plantain maturity. These include fruit diameter, age of the bunch, angularity of the fruit, length of the fruit, and peel color (Johnson *et al.*, 1998). The stage of maturity for harvest depends on the intended market destination (Johnson *et al.*, 1998). Locally marketed plantains can be harvested at a more advanced maturity stage compared to export market fruit. Export market destined fruit should be harvested the day before or the same day of shipment (Ogazi, 1996). Plantain maturity is related to the diameter of the fingers. This is determined by measuring the diameter of the fruit at its midpoint with a pair of calipers (Ogazi, 1996).

Another method for estimating plantain maturity is to record the age of the bunch. The time from when the fruit bunch first becomes visible (Shooting) is recorded. Bunches can be tagged with different colored ribbons at the time of shooting, and subsequently harvested after the appropriate time for the particular cultivar, based on the season of the year and experience (Johnson *et al.*, 1998). The colour of the ribbons is changed weekly to coincide with the time of shooting and subsequently the age of the bunch (Johnson *et al.*, 1998).

A third method used to determine harvest maturity is to observe the shape (fullness) and angularity of the fruit. Immature fruit is angular in cross sectional shape and has distinct ridges (Ogazi, 1996). As the fruit matures, it becomes less angular and more rounded or full. The degree of roundness differs between cultivars and location of the hand on the bunch. Typically, the fullness of the fruit on the middle hand is measured. The appropriate shape to harvest the fruit depends on the market destination. Fruit intended for the domestic market should be harvested when the fruit shape is nearly round (Johnson *et al.*, 1998).

A fourth way of estimating plantain bunch maturity is to measure the length of the edible pulp portion of the fruit from the fingers in the middle hand. The length should be a minimum of 15cm for the domestic market and 18cm for the export market (Johnson *et al.*, 1998). Finally, peel color is another frequently used method of assessing fruit maturity. The peel remains green throughout growth and development of the fruit until it reaches physiological maturity. It then changes to a yellow color during ripening (Ogazi, 1996).

In addition, it is also better to represent color chart for determining maturity here. However, plantain fruit should be harvested when the peel is green in color to withstand the rigors of handling and distribution (Johnson *et al.*, 1998). Internal fruit composition changes dramatically during plantain fruit ripening. At physiological maturity, the fruit is fully developed in size, green in peel colour, and at its highest level of starch (Ogazi, 1996). The starch will progressively be converted to sugar as ripening progresses.

The stage of harvest maturity of plantains will depend on the target market. Plantains for local market are harvested at a more advanced stage of maturity than those for exportation (Ogazi, 1996). However, if the fruit is too mature at harvest, particularly following

irrigation or rainfall, fruit splitting can occur during handling. Also, mature fruit may ripen prematurely during transport or storage (Ogazi, 1996).

**2.5 Pretreatment of Banana slices**

Drying is the most common method of food preservation to enhance storability and add value to the product. During hot air drying, enzymatic and non enzymatic browning reactions can affect the quality of fruit and vegetables in terms of color and flavor. Previous researches have reported the effect of drying on the color of various products like mushrooms (Kotwaliwale, 2007), bananas (Cano-Chauca, 2002; Krokida, 2001; Maskan, 2000), and grapes (Doymaz, 2002). Ascorbic acid (Demirel, 2003) is the most common anti-browning agent, selected for use in fresh-cut fruits. However, the pre-treatments affect the drying rate of various foodstuffs in a different way, according to the differences in tissue properties (Walde, 2006).

Food consumption patterns are rapidly changing all over the world. Consumer food choices have been attributed, in part, to the rise in health problems. Therefore, the positive health impact of nutrients in fruits and vegetables has become one of the consumer's chief concerns. However, the practices of fresh-cut processing promote a faster physiological deterioration, biochemical changes, enzyme activity and microbial degradation of the product.

Enzymatic browning may be controlled by various methods. Application of antibrowning agents is a popular approach for retarding enzymatic browning in fresh-cut fruits and vegetables. Surface treatments by dipping fresh-cut products in the appropriate antibrowning agents can effectively help to delay discoloration. Nature identical antibrowning agents are a favorite group because they are generally recognized as safe (GRAS) status and are non-toxic. Several nature identical antibrowning agents extensively used to control excessive browning include ascorbic acid (AA), citric acid (CA) and oxalic acid (OA) that are weak organic acids found in fresh fruits and vegetables (Son, 2001; Lee, 2003; Gonzalez, 2004).

Antibrowning agents are compounds that act to prevent the browning reactions. Chemical treatment with the use of antibrowning agents is an effective and frequently employed method for controlling the enzymatic browning in several fresh-cut fruits and vegetables. Antibrowning agents can be divided into six groups including acidulants, reducing agents,

chelating agents, complexing agents, enzyme inhibitors and enzyme treatments, based on inhibitory mechanisms (Son, 2001; Garcia, 2002; Altunkaya, 2009; Altunkaya, 2008). Acidulants, such as citric acid, oxalic acid, tartaric acid, malic acid, phosphoric acid and hydrochloric acid, retard browning by lowering the pH of the product to minimize the activity of poly phenol oxidase (PPO).

AA, CA and OA are weak organic acids widely found in plant tissues (Rico, 2007; Li, 2008). AA is a natural component in fresh fruits and vegetables and greatly accepted as an important nutrient for human health (Kabasakalis, 2000; Pernice, 2009). CA is the most abundant acid in plants, especially in citrus fruits (Pernice, 2009; Campo, 2006). OA is a common constituent of many plants such as asparagus, broccoli, carrots, garlic and spinach (Naude, 2007; Kayashima, 2002). These organic acids have been reported often for their antibrowning activity in fresh cut fruits and vegetables ( Bico *et al.*, 2009) and have general recognized as safe (GRAS) status (PHS, 2008).

Browning of food is widespread which takes place during processing and storage. Browning usually impairs the sensory properties of products due to associated changes in the color, flavor and softening besides nutritional properties (Martinez and Whitaker, 1995).

Sulfites are highly effective in controlling browning. Sulfiting agents (sulfer dioxide, sodium sulfite, sodium and potassium bisulfites and metabisulfites) have been added to many foods to prevent enzymatic and non-enzymatic browning (Sapers and Hicks, 1989).

The most important agents of food spoilage are microorganisms; others are the reactions due to enzymes in the foods; direct oxidation; the desiccation of moist foods; the absorption of foreign odors and flavors; contamination with injurious chemicals; mechanical damage by animal and insect pests; and causes peculiar to a particular process of preservation, for example, the corrosion of container in canning. A great deal of research has been directed to overcoming these problems, however, good the resultant products are they cannot in flavor and other characteristics with the fresh banana fruit. Indeed, an important constraint on the large-scale development of banana products since the fresh fruit is available throughout the year in most part the world (Dauthy, 1995).

## 2.6 Drying of Banana slices

Banana is one of the important high sugar tropical fruit crops grown in many countries and is very susceptible to quality deterioration. Conventional hot air drying, which is the oldest method used in food preservation, has been widely applied for drying bananas. Due to the high sugar contents in bananas, drying them normally requires high temperatures and prolonged drying times, which can cause serious adverse changes in flavor, color, texture and nutrients of the finished products (Maskan, 2000). The major disadvantages of hot air drying are low energy efficiency and lengthy drying times during the falling rate period. Because of the low thermal conductivity of food materials in the falling rate period, heat transfer to the inner sections of foods during conventional heating is limited (Feng and Tang, 1998).

Among the conventional dryers used in banana drying the following are distinguished: the trays dryer, where the time of drying is significant; the drum dryer, where the product does not present good quality, above all for not presenting uniformity in the drying; the spray dryer, that it makes possible a high quality product; however, the capital investment and operational costs are significant, what makes unfeasible its use for medium and small capacity industries (Hufenuessler and Kachan, 1986; Maskan, 2000; Nury *et al.*, 1973). The rotary dryer with inert bed (RDIB) is an alternative technically viable, because in the processing of other foodstuffs good quality powdered products were obtained (Finzer *et al.*, 1993).

Conventional air-drying is the most frequently used dehydration operation in food and chemical industry and as such preferably used in drying of banana and banana chips. In this case, the drying kinetic is greatly affected by air conditions (air temperature, air humidity and air velocity) and material properties (including the characteristic dimension), while other process factors exert negligible influence (Krokida *et al.*, 2003; Kiranoudis *et al.*, 1997). Hence, optimization of the drying operations must minimize the consumption of energy and minimize the processing effect on the biologic quality of the dried products (Belghit *et al.*, 2000). The optimization of drying parameters of mechanical dryer also leads to the increased production rate of dried products (Ibrahim *et al.*, 2009).

A typical spray dryer can produce 70 kg powder per hour to give yields of 8 to 11% of the fresh fruit, while drum-drying gives a final yield of about 13% of the fresh fruit. In the latter method the moisture content is reduced to 8 to 12 % and then further decreased to 2 % by drying in a tunnel or cabinet dryer at 60° C (FAO, 2004).

**2.7 Banana Powder**

Banana is one of the most consumed fruits in tropical and subtropical regions. New economical strategy to increase utilization of banana includes the production of banana flour when the fruit is unripe, and to incorporate the flour into various innovative products such as slowly digestible cookies (Aparicio *et al.*, 2007), high-fiber bread (Juarez *et al.*, 2006) and edible films (Sothornvit and Pitak, 2007). The preparation of banana flour from unripe banana has been reported (Rodriguez *et al.,* 2008), and the flour has been shown to possess thickening and cooking properties nearly identical to those of isolated starch (Suntharalingam and Ravindran, 1993).

It will be interesting to prepare banana flour from ripe fruits. Ripe banana flour can potentially offer new products with standardized composition for various industrial and domestic uses. Banana flour prepared from ripe banana containing a quantity of sugar is suitable for incorporation into food products requiring solubility, sweetness and high energy content. Commercial banana flour production is not yet common in Asia however this industry is gaining popularity in major banana producing countries in Africa (Emaga *et al.*, 2008).

The clear advantage presented by green banana flour includes a high total starch (73.4%); resistant starch (17.5 %) and dietary fiber content (~ 14.5%) (Juarez *et al.*, 2006). Due to the high content of these functional ingredients, regular consumption of green banana flour can be expected to confer beneficial health benefits for human (Rodriguez *et al.*, 2008).

Banana fruit dried to produce powder commercially, is produced by spray-drying, or drum-drying (Meadows, 2007), it is dried at 105°C, with final moisture content of 2-5% and average drying ratio (fresh to dried weight) of 13:1 (Al-Gendy, 1981).

*Kibuzi,* the most popular cooking banana type in Rakai, was used for banana flour processing. Bunches of fully mature and undamaged *kibuzi* were purchased from

suppliers in Kawanda and were processed into flour. The average weight of the big bunches of *kibuzi* was 30 kg. Each bunch had an average of ten clusters of about 20 fingers each. The banana fingers were detached, washed and steamed traditionally for 40 minutes by covering with banana leaves without peeling. Steaming was chosen because it does not entail immersing the banana into water and it preserves the natural flavor (Muyonga , 2001). The loosened peels were stripped off the warm steamed banana fingers by hand. The bananas were then sliced and sun-dried for 48 hours. The average flour yield based on finger weight of banana was 2.45%. The dried banana was milled to pass through a 1mm screen (Cadmach, Machinery Co. *Pvt., Ltd.,* Ahmedabad, India).

Banana powder is prepared from dessert bananas after mashing and drying the pulp in drum or spray dryers. The dried product is pulverized and passed through a 100-mesh sieve, producing a free-flowing powder which is stable for at least one year after packaging. This powder is used in bakery and confectionery industries, in the treatment of intestinal disorders and in infant diets (Adeniji *et al.*, 2006).

Instant plantain flours were prepared from ripe and unripe plantain (*M. paradisiaca*) fingers, by cooking and subsequent oven dehydration at 76°C and at 88-92°C, respectively, by Ukhun and Ukpebor (1991).

Preparation of flour: Finger samples were collected from the second hand from the proximal end of the bunch following the recommendation of Baiyeri and Ortiz (2000) the same day the bunch was harvested. Some samples were immersed in a plastic bowl with potable water and then sliced longitudinally into two with the aid of stainless kitchen knife. Blanching was carried out on some samples by dipping fingers in hot water at 100°C for 5, and 10 minutes before slicing. Some samples were peeled and dried directly in the oven without treatment, which served as control.

Sliced fruits were placed in petri dishes and covered with filter paper to prevent contamination. Drying was carried out in Forced-Air Moisture Extraction Plus II Oven, Sanyo Gallenkamp PLC, United Kingdom, at 65°C for about 48 hours and milled with the aid of stainless Kenwood Chef Warring Blender, Model KM001 (0067078) series.

Flour can be made from green unripe banana, cooking banana or plantain. Fruits are hand-peeled and sliced or chopped into pieces about 5-10 mm thick. The slices will be dried in the sun by spreading out the slices on mats, on bamboo framework, on cement

floors, or on a roof or sheets of corrugated iron or simply on a swept bare ground. Various designs of solar dryers can also be used, or they may be dried in ovens, over fires, in a cabinet dryer or tunnel dryer. The fruits are either sun-dried which is the former, oven-dried, the latter or foam-mat dried which will be described now. Sun and oven-drying methods have been used for drying of plantain and banana (Johnson *et al.*, 1998; Demirel and Turhan, 2003) with some success, the introduction of foam-mat drying brought much more (Falade and Olugbuyi, 2009). *Musa spp.* Especially cooking banana is cheaper relatively when compared with wheat and other cereals for the production of flours therefore processing of cooking banana should be encouraged.

In foam-mat drying plantain puree was prepared by blending steam blanched plantain and distilled water for 2 minutes in a warring blender to produce 0.4% total solids (TS) paste. A 20% (w / w) glyceryl monostearate (GMS) suspension is prepared by dissolving a known weight of GMS in hot water at 100°C. The 20% suspension is added to obtain a 0.02% GMS in the plantain paste. The mixture of plantain paste (30% TS) and GMS suspension are then transferred into a Kenwood Chef mixer and whipped at maximum speed for 4 minutes until homogenous foam is obtained. The whipped foam could be extruded using a manual Euro line icing syringe (Model 5 Nozzles stainless steel 19 cm, Euro line, Essex, UK) with an outlet orifice of 4 mm diameter on a stainless steel wire mesh and dried in a cross-flow Gallenkamp Oven at 60°C for 45–90 minutes. The dried plantain is scraped off and packaged in low density polyethylene (100 μm) to prevent moisture absorption (Falade and Olugbuyi, 2009). After drying, the chopped pieces have a moisture content of about 5-10%. The dried pieces were ground and usually sieved to produce the flour. The flour is packaged in moisture proof bags. The dried slices are stored and only converted to flour when needed since the flour tends to lose its flavor rapidly or may absorb moisture (hygroscopic) and become mouldy.

Powder could be prepared from fully ripe banana, cooking banana or plantain. Fruits are washed, hand-peeled and chopped fairly coarsely. The material is converted into a paste by passing through a mill to reduce the particle to a colloidal size (below about 10 μm). A 1-2% Sodium metabisulphite solution is added at this stage to improve the color of the final product or to prevent discoloration. The material is then dried. Drying can be achieved, either in a spray dryer (at 30 to 32°C and less than 30% Relative Humidity under vacuum) or a drum dryer (product temperature should not exceed 94°C). After

drum drying it might be necessary to further dry the product in a cabinet dryer. The final moisture content of the powder should be about 2% and should be stored in moisture proof bags (Thompson, 1995).

Banana, plantain and cooking banana (*Musa spp)* may be processed into many products at different stages of physiological maturity; unripe, ripe, overripe or in a number of ways such as frying, grilling, boiling and drying. According to Demirel &Turhan (2003), drying adds value to banana in addition to preservation. Moisture removal from plantain seems to be an appropriate and economical means of preserving *Musa spp*, resulting in shelf stable and convenience products. Currently, unripe plantain flour is being processed into a thick paste product known as 'amala' in the western part of Nigeria, which is medically recommended for diabetic patient (Adeniji *et al.*, 2006). Ripe banana powder is used in bakery and confectionery industries, in infant diets and the treatment of intestinal disorders (Adeniji *et al.*, 2006).

Improved cultivars of plantain and banana may provide high quality whole flour from the entire fruit for livestock feed, which may eventually provide protein in human diet from consumption of meat and other products of livestock (Thompson, 1995.). Such flour may be employed in traditional dishes for human consumption based on their nutritional profiles. Although, there is need to investigate the application of whole *Musa* flour in baking and confectioneries from the point of view of their pasting properties but that notwithstanding it has recorded success when used in addition to the conventional wheat flour. The use of entire fingers of plantain and banana could be a rapid approach in flour production with improved levels of nutrients, especially minerals, which are concentrated in the peel (Izonfuo and Omuaru, 1988).

Production of flour has been carried out by peeling and slicing green fruit, exposure to sulphur dioxide gas, then drying in a counter-current tunnel dryer for 7 to 8 hr. with an inlet temperature of 75° C and outlet temperature of 45° C, to a moisture content of 8%, and finally milling. (FAO, 2004).

Raw bananas should be allowed to ripe in the Laboratory in an incubator at 180 - 200 °C and a RH of 68-75% till the fruit becomes soft. The fruits are then peeled and pulp was then cut into small pieces with a stainless steel knife. The macerated pulp is then dried at 600 °C under 58 cm of vacuum. After 9 hours the dried product is pulverized and passed

through a 50 mesh sieve and the powder is stored in air tight polythene bags in air tight containers. Spray drying of banana pulp yielded banana powder which is a hygroscopic material needing special care for preventing infection. Banana powders were found to contain many of the nutrients that were normally required for the general well being of the body (Ikisan, 2009).

**Peculiarities of banana powder**

1. Banana powder is rich in carbohydrates and hence a rich source of energy.
2. Banana powder when cooked is easily digested and nutrients are absorbed well.
3. Banana powder can augment the diets of small children and convalescents with much beneficial effects.
4. Banana Powder is a fair source of B vitamin, calcium, iron and potassium.
5. Banana powder contains appreciable amounts of many trace minerals as well as fiber.
6. Banana powder is very starchy and can be used in blends with other cereal powders for various preparations.

   (Nutrition resource, 2010).

## 2.8 Chemical Composition and Nutrient Content

The chemical composition of plantain varies with the variety, maturity, degree of ripeness and where it is grown (soil type). The water content in the green plant is about 61% and increases on ripening to about 68%. The increase in water is presumably due to the breakdown of carbohydrates during respiration. Green plantain contains starch which is in the range of 21 to 26%. The starch in the unripe plantain is mainly amylose and amylopectin and this is replaced by sucrose, fructose, and glucose during the ripening stage due to the hydrolysis of the starch (Marriott *et al.*, 1983). The carbohydrate content reduces to between 5 and 10% when ripe. The sugar content is between 0.9 to 2.0% in the green fruit but becomes more prominent in the ripe state. The titrable acidity of plantain is about twice that of sweet potato (Aurand *et al.*, 1987).

Plantains therefore have a high carbohydrate content (31 g/100 g) and low fat content (0.4 g/100 g). They are good sources of vitamins and minerals (Adeniji, *et al.*, 2006), particularly iron (24 mg/kg), potassium (9.5 mg/ kg), calcium (715 mg/kg), vitamin A, ascorbic acid, thiamin, riboflavin and niacin. The sodium content (351 mg/kg) is low in

Briav, 1979). ). Generally, bananas contain a considerable amount of mineral elements and could therefore serve as a good source of mineral supplement in human/animal diets.

It is reported that plantain composes of mainly water, 60% and 27-31% carbohydrate with only 2-3%, protein about 1% fat (Oyenuga,1968; Simmonds,1970; Ketiku,1976). The protein is deficient in methionine and tryptophan (Omole, *et al.*, 1978). Comparatively, plantain is rich in phosphorus, calcium and iron with 34, 10 and 0.55mg/100g of pulp respectively (Oyenuga,1968). Other minerals found in plantains includes, potassium, magnesium, manganese, copper, iodine, zinc, cobalt. Plantain is also a very good source of pro-vitamin A, vitamins B6 and vitamin c (0.285, 0.65, 17.0mg/100g of pulp respectively). A significant of amount of thiamin, riboflavin, nicotinic, acid and folic acids are also reported to be found in this fruit (Marriott *et al.*, 1983). Plantain is rated as an important source of energy and provides about 104cal/100g of the pulp (Oyenuga, 1968).

Of special interest are food sources rich in anti-oxidant vitamins (vitamins C, A, and E), calcium (Ca), magnesium (Mg), and potassium (K), (Marisa, 2006). Plantain (*Musa spp.*) is an important dietary source of carbohydrate in the humid tropical zones of Africa, Asia and South America (Robinson, 1996). Plantain is rich in vitamins A, C and B group as well as minerals such as calcium and iron (Marriott and Lancaster, 1983; Robinson, 1996). Plantain provides between 9 %and 35 % of the total calories in the diets of more than 14 million people in sub-Sahara Africa (Robinson, 1996). The banana is shown to contribute to the recommended daily requirements of K, Mg, Cu and B (Hardisson *et al.*, 2001).

According to Louis *et al.* (2009), Yellow plantain variety gave higher yield of starch than the white variety. The two varieties differed in the purity of starch extract; white plantain starch contained: ash (1.09%), protein (0.640%) and fat (0.276%) while yellow plantain starch contained: ash (0.95%), protein (0.325%) and fat (0.403%). The amylose content of yellow plantain starch (24.36% (apparent), 26.13% (total)) was similar to that of white plantain starch (24.24% (apparent), 26.01% (total).

In a research conducted by Adegboyega (2006) on the proximate chemical composition of the carbohydrate constituents and the amino acid make-up of green and ripe plantain, the quantity of total sugars considerably increased during ripening from 3.0 to 31.6% in the

peel and from 1.3 to17.3% in the pulp while starch concentration decreased from 50 to 35% and from 83 to 66% in the skin and the pulp, respectively. The skin was richer in cellulose (10%) and hemicelluloses (13%) than the pulp which had 1.4% cellulose and 1.3% hemicellulose. The pulp protein was abundantly rich in arginine, aspartic acid and glutamic acid. Methionine was present in the lowest amount with tryptophan and cystine conspicuously being absent.

The average composition of raw banana per each 100g is as follows: water, 74.2g; energy, 92Kcal; fat, 0.48g; protein, 1.03g; carbohydrate, 23.43g; fiber, 2.4g; potassium, 396mg; phosphorus, 20mg; iron, 0.31mg; sodium, 1mg; magnesium, 29mg; calcium, 6mg; zinc, 0.16mg; selenium, 1.1mg; vitamin C, 9.1mg; vitamin A, 81IU; vitamin $B_1$, 0.0045mg; vitamin B2, 0.10mg; vitamin E, 0.27mg; niacin, 0.54mg (UADA, 2009).

The average composition of banana powder per 100gm is as follows: Energy, 153Kcal; Fat, 0.2gm; Protein, 1.3gm; Carbohydrate, 36gm; Calcium, 10gm; Potassium, 384mg; Phosphorus, 50mg; Iron, 0.40mg; Sodium, 1.2mg; Magnesium, 42mg; Copper, 0.16mg; Zinc, 0.16mg; Choloride, 78.5mg; Vitamin C, 15mg; Vitamin $B_1$, 0.0045mg; Vitamin $B_2$, 0.10mg. (Health vitamins guide, 2008).

**Table 2.2: The nutritional values of plantain (Banana) per 100g of edible fresh portion**

| SL.No. | **Nutrient** | **Amount** | **Daily Recommended Intake** |
|---|---|---|---|
| 1 | Water | 74% | 240ml |
| 2 | Carbohydrates | 23% | 300grams |
| 3 | Protein | 1% | 50grams |
| 4 | Fats | 0.5% | 65grams |
| 5 | Fibre | 2.5% | 25grams |

(Dickinson, 2000 and Edinformatics, 2006)

**Table 2.3: Mineral content of plantain (nutrients per 100g ripe, edible plantain)**

| SL.No. | **Mineral** | **Amount** | **Daily Recommended Intake** |
|---|---|---|---|
| 1 | Sodium | 1mg | 2400mg |
| 2 | Potassium | 400mg | 3500mg |
| 3 | Calcium | 6mg | 1000mg |
| 4 | Magnesium | 34mg | 400mg |
| 5 | Phosphorus | 28mg | 1000mg |
| 6 | Iron | 0.3mg | 18mg |
| 7 | Copper | 0.1mg | 2mg |
| 8 | Zinc | 0.2mg | 15mg |
| 9 | Chloride | 79mg | 3400mg |
| 10 | Manganese | 0.4mg | 2mg |
| 11 | Iodine | 8micrograms | 150micrograms |

The plantain nutrition group (UK); Dickinson, 2000.

**Table 2.4: Nutritional Data for Banana Powder (per 100g)**

| SL.No. | **Nutrient** | **Amount** |
|---|---|---|
| 1 | Total Carbohydrate | 88g |
| 2 | Protein | 4g |
| 3 | Total Fat | 2g |
| 4 | Potassium | 1491mg |
| 5 | Calcium | 22mg |
| 6 | Magnesium | 108mg |
| 7 | Zinc | 0.61mg |
| 8 | Iron | 1.15mg |
| 9 | Phosphorus | 74mg |

## 2.9 Processing Quality

The bulk of the banana, cooking banana and plantain are eaten either as raw, in the ripe state, or as a cooked vegetable, and only a very small proportion are processed in order to obtain a storable product. Generally, preserved products do not contribute significantly to the diet of the millions of people who eat banana, cooking banana and plantain, however in some countries or areas, the processed or preserved products are important in periods when food is scarce. Processing is recognized as a way of preserving the fruit. Yet the proportion of fruits processed and the suitability of the various Musa groups to processing is relatively unknown. New Musa hybrids should therefore be screened for their processing quality or suitability for processing (Thompson, 1995).

The ripe banana is utilized in a multitude of ways in the human diet, from simply being peeled and eaten out of hand to being sliced and served in fruit cups and salads, sandwiches, custards and gelatins, being mashed and incorporated into ice cream, bread, muffins and cream pies (*Adeniji et al.*, 2006). Ripe plantains are often sliced lengthwise,

baked or boiled, and served (perhaps with a garnish of brown sugar or chopped peanuts) as an accompaniment for ham or other meats. Ripe plantain may be thinly sliced and cooked with lemon juice and sugar to make jam or sauce, stirring frequently during 20 or 30 minutes until the mixture jells. Whole, peeled plantain can be spiced by adding them to a mixture of vinegar, sugar, cloves and cinnamon which has boiled long enough to become thick and then letting them cook for 2 minutes (Chandler, 1995).

Banana puree is important as infant food and can be successfully canned by the addition of ascorbic acid to prevent discoloration. The puree is produces on a commercial scale in factories close to banana fields and packed in plastic-lined 10 cans and 55-gallon metal drums for use in baby foods, cake, pie, ice cream, cheesecake, doughnuts, milk shakes and many other products (Ogazi, 1996).

In Polynesia, there is a traditional method of preserving large quantities of bananas for years as emergency food in case of famine (Ogazi, 1996). A pit is dug in the ground and lined with banana and Heliconza leaves. The peeled bananas are wrapped in Heliconza leaves, arranged in layer after layer, then banana leaves are placed on top and soil and rocks heaped over all. The pits remain unopened until the fermented food, called "masi", is needed.

In Costa Rica, ripe bananas from as entire bunch are peeled and boiled slowly for hours to make thick syrup which is called "honey" (Ogazi, 1996).

Through experimental work with a view to freezing peeled, blanched, sliced green plantain, it has been found that, with a pulp-to-peel ratio of less than 1:3 the fruits turn gray on exposure to air after processing and this discoloration is believed to be caused by the high iron content (4.28p/m) of the surface layer of the flesh. Its reaction to the tannin normally present in green bananas and plantains. At pulp to peel ratio of 1.0, the tannin level in green bananas is 241.4mg; at 1.3, 151.0mg, and at 1.5, 112.6mg, per 100g (Ogazi, 1996). Therefore, it is recommended that for freezing, green bananas should be harvested at a stage of maturity evidenced by 1.5 pulp-to-peel ratio. Such fruits have a slightly yellowish flesh, higher carotene content and are free of off-flavors. The slices are cooked by the consumer without thawing (Ogazi, 1996) are free of off-flavors. The slices are cooked by the consumer without thawing (Ogazi, 1996).

Completely green plantains are 50% flesh and 50% peel (Ogazi, 1996). Plantain for freezing should have a pulp content of at least 60% for maximum quality in the ultimate food product, but a range of 55 to 65% is considered commercially acceptable (Ogazi, 1996).

In Ghana, plantains are consumed at 5 different stages of ripeness (Chandler, 1995). Fully ripe plantains are often deep fried or cooked in various dishes. A Ghanian pancake called "fatale" is made of nearly full ripe plantains and fermented whole meal dough of maize, seasoned with onions, ginger, pepper and salt, and fried in palm oil. "Kaklo" is the same mix but thicker and rolled into balls which are deep-fried. Because home preparation is laborious, a commercial dehydrated mix has been developed. In Ghana, green plantains are boiled and eaten in stew or mashed, together with boiled cassava, into a popular plastic product called "fufu" which is eaten with soup. Because of the great surplus of plantains in summer, technologists have developed methods for drying and storing of strips and cubes of plantain for house use in making "fufu" out of season. The cubes can also be ground into plantain flour. Use of infra red, microwave, and extrusion systems have resulted in high-quality finished products. Processing has the added advantage of keeping the peels at factories where they may be converted into useful byproducts instead of being added to the bulk of household garbage (Chandler, 1995).

Banana or plantain flour, or powder, is made domestically by sun drying slices of unripe fruits and pulverizing (Anon, 1999). Commercially, it is produced by spray-drying, or drum-drying, the mashed fruits (Anon, 1999). The flour can be mixed 50-50 with wheat flour for making cupcakes. Two popular Puerto Rican foods are "pasteless" and "alcapurais" both are pastry stuffed with meat, the first is wrapped in plantain leaves and boiled the latter is fried. The pastry is made of plantain flour or a mixture of plantain with cassava or cocoyam Commercial production and marketing of fried green plantain and banana chips has been increasing in various parts of the world over the past 25 years and these products are commonly found in retail groceries alongside potato chips and other snack foods.

In Africa, ripe bananas and plantains are also processed into beer and wine. The Tropical Products Institute in London has established a simple procedure for preparing acceptable vinegar from fermented banana rejects (Anon, 1999)

Cavendish (AAA) banana is a dessert type of banana that is different from Plantain (AAB), a cooking banana. The plantain is extensively produced in Africa, the Caribbean and Latin America, whilst Cavendish is distributed in all continents (Aurore *et al.*, 2008). New economical strategy to increase utilization of banana includes the production of banana flour when the fruit is unripe, and to incorporate the flour into various innovative products such as slowly digestible cookies (Aparicio *et al.*, 2007), high-fiber bread (Juarez *et al.*, 2006) and edible films (Rungsinee and Natcharee, 2007).

Banana, is utilized in the human diet, are often sliced lengthwise, baked or broiled and served. It may be thinly sliced and cooked. Banana or plantain flour, or powder, is made domestically by sun-drying slices of unripe fruits and pulverizing (Suntharalingam and Ravindran, 1993).

Dried bananas, or so-called "banana figs" are peeled firm-ripe bananas split lengthwise, sulphured and oven-dried to a moisture content of 18 to 20%. Wrapped individually in plastic and then packed by the dozen in polyethylene bags and encased in cartons, they can be stored for a year at room temperature between 24° to 30°C and they are commonly exported. The product can be eaten as a snack (Morton, 1987).

Bananas and plantains are usually prepared in different forms; they can be fried, roasted, boiled, pounded and used to form porridges and most often these are eaten with various sources, vegetables and other food complements (Lemaire *et al.* 1997; Emaga *et al.*, 2000).

Primary Product: Boiled plantain, Plantain pastry, Plantain pastry mixed with beans, Fried plantains, Plantain fritters, Plantain Chips: Plantain chips are the most popular plantain products in Nigeria. They are prepared by frying round slices of unripened or slightly ripened plantain pulp in vegetable oil. Best quality plantain chips have been obtained in Cameroon by frying round slices of pulp (2 mm thick) in refined palm oil between 160 and $170^0$C for 2 to 3 minutes (Lemaire *et al*, 1997).

## 2.10 Justification of the research

From the above reviews, it showed that so many works were done by many researchers on preservation of banana (drying, freezing, canning etc.), various banana products (banana powder, chips, paste, honey etc.), different value added products (ice-cream, bakery products, baby foods etc.) and so on. In Bangladesh various types of banana products are uncommon and very fewer works were done on preparation and analysis of phyco-chemical properties of banana powder during storage. By this research will help to know how the banana powder prepared and phyco-chemical properties of banana powder changes during storage?

# CHAPTER III
# MATERIALS AND METHODS

# CHAPTER III

# MATERIALS AND METHODS

This study was conducted under the Department of Food processing and Preservation, Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period of January 2013 to July 2013. In this chapter manufacturing process of banana powder and physic-chemical properties of banana powder were discussed.

## 3.1 Materials

The fresh ripe Amritasagar variety of banana was selected for the research work. The chemicals and reagents were used from laboratory stock. Chemicals and solvents used in the study were of analytical reagent grade and water was distilled. High density polythene bags (0.0508 mm) were used as the packaging material.

## 3.2 Methods

### 3.2.1 Preparation of Banana Powder

The fresh ripe Amritasagar variety of banana (stage 5 of ripeness – more yellow than green, Emaga *et al,* 2008) was collected from nearly village of HSTU, Dinajpur. Fruits are then washed well in clean water to remove dirt and surface micro-organisms. Washed ripe banana fruits were sorted from damaged or rotten fruits. Fruits were hand peeled and chopped into pieces (approx. 2 mm thick) using a stainless steel knife.

Four different plastic bowls were taken and numbered as 1, 2, 3 and 4. The first (1) bowl was empty. The second (2) bowl was poured with 0.5% of citric acid solution (1L). The third (3) bowl was poured with 0.1% of potassium metabisulfite (KMS) solution (1L). The fourth (4) bowl was poured with 0.5% of citric acid solution (0.5 L) and 0.1% of potassium metabisulfite (KMS) solution (0.5 L). Then 0.5Kg of sliced pieces was placed in each of the bowl.

The slices of the first bowl was treated as control sample and the solutions of the other bowls were used as pretreatment to control browning and also to retard change in nutritional composition. The first bowl was solution free, so soaking is done for 10 minutes in each of the other bowls. After that the soaked slices were removed from the

solutions and allowed to drain in plastic sieve. Then the slices were spread uniformly on four different drying trays.

The trays were placed in a drying cabinet (Model- 136-12, Seoul, Korea) and dried at $60^0$C for 24 hours. Then the dried chips were separated and ground into powder by using a blender (Jaipan CM/L- 7360065, Japan). After that powder sieved using stainless steel sieve (Sieve no. MIC- 300) and packed in high density polyethylene bags (thickness of 0.0508 mm). The obtained powder was sealed (by bag sealer) and stored at room temperature ($21^0$-$32^0$C).

### 3.3 Yield of banana powder

The yield of banana powder was calculated from the weight measurement of the powder obtained after drying, the total weight of fresh whole bananas was taken. The weight of the pulp and peels was also measured. The yield was calculated as:

$$\%\,Y = \frac{\text{Weight of dried banana powder}}{\text{Weight of banana pulp}} \times 100$$

Where,

%Y = Percent yield

Weight of banana pulp = Weight of whole bananas – Weight of peels

### 3.4 Physical Analysis

#### 3.4.1 Water-holding capacity (WHC) and oil-holding capacity (OHC) of banana powder

At first eight test tubes were taken. Four test tubes were used to determine water holding capacity and another four oil holding capacity. Each test tube were marked as $S_1W$, $S_2W$, $S_3W$, $S_4W$ (for WHC) and $S_1O$, $S_2O$, $S_3O$, $S_4O$ (for OHC) and weighted. For WHC 10ml distilled water was pipetted to tubes and 1g of banana powder was added to each tube as marked. The same procedure was applied for OHC, but 10ml commercial soybean oil were added to tubes instead of distilled water and closed with cork and mixed well by shaking with hands, also with the help of a vibrator. Then the tubes were heated with the help of a stand in a water bath at 80°C for 10 minutes. Tubes were centrifuged at 4000 rpm for 20 min, the supernatant was decanted, and the tubes were allowed to drain for 10 min at a 45°angle. The second weight was taken. First weight was subtracted from the

second weight and we got a value. Finally subtracting one from the measured value we obtained the g of water or oil retained by per g of powder (Rodrı´guez-Ambriz *et al.*, 2008 and some modification).

### 3.5 Chemical Analysis

The banana powders were analyzed for their moisture, ash, fat, protein, total carbohydrate and mineral contents (K, Ca, Mg, Zn, Fe and P). All the determinations were done in triplicate and the results were expressed as the average value.

#### 3.5.1 Determination of Moisture content

This was determined according to the AOAC method (2004), using the oven drying method. A dry clean crucible was oven dried for about 30 minutes at $800^0$ C, and cooled in desiccators. The weight of the crucible was taken after cooling as ($W_1$). 5g of sample was weighed into the crucible and the weight was recorded as ( $W_2$ ) the crucible and its content was transferred into the oven at temperature of $105^0$C to dry for about 24 hours, after which the crucible was cooled in desiccators and the final weight was taken as ($W_3$). This was carried out for all the samples.

**Calculation:**

$$\% \text{ of moisture} = \frac{\text{Loss in weight due to time}}{\text{weight of sample taken}} \times 100 = \frac{W2 - W3}{W2 - W1} \times 100$$

#### 3.5.2 Determination of total mineral (Ash)

Ash content of foodstuff represents inorganic residue remaining after destruction of inorganic matter. Total ash content was determined by AOAC method 14066 (1975).

5g sample was taken in a dry, clean porcelain dishes and weighed accurately. Hot air oven method was applied to remove the moisture. Then the sample was burned using an electric heater. This was done to avoid the loss of sample in the Muffle furnace at higher temperature of $550^0$C and ignited until light gray ash resulted (or to constant weight). The sample was then cooled in desiccators and weighed.

**Calculation:**

$$\% \text{ of ash} = \frac{\text{Weight of the ash}}{\text{Weight of the raw sample}} \times 100$$

### 3.5.3 Determination of crude fat

The crude fat content was determined by AOAC method (1984). Ether soluble material in a food is extracted from an oven dried sample using a Soxhlet extraction apparatus. The ether is evaporated and the residue weighed. The ether extract or crude fat of a food represents, besides the true fat (Triglycerides), other materials such as phospholipids, sterols, essential oils, fat-soluble pigments, etc., extractable with ether. Water soluble materials are not extracted since the sample has been thoroughly dried prior to extraction with anhydrous ether or petroleum ether.

The sample remaining after moisture determination was transferred to a thimble and plugged the top of the thimble with a wad of fat free cotton. The thimble was dropped into a fat extraction tube of a Soxhlet apparatus. The bottom of extraction tube was attached to a Soxhlet flask. Approximately 75 ml or more of anhydrous ether was poured through the sample in the tube into the flask. The top of the fat extraction tube was attached to the condenser. The sample was extracted for 16hours or longer on water bath at $70^0$C to $80^0$C. At the end of the extraction period, the thimble from the apparatus was removed and distilled off most of the petroleum ether by allowing it or collected in Soxhlet tube. The petroleum ether was poured off when the tube was nearly full. When the petroleum ether had reached small volume, it was poured into a small, dry beaked through a small funnel containing plug cotton. The flask was raised and filtered thoroughly, using ether. The ether was evaporated on steam bath at low temperature and was then dried at $100^0$C for 1 hour, cooled and weighed.

**Calculation:**

$$\% \text{ of crude fat} = \frac{\text{Weight of ether soluble material}}{\text{Weight of sample}} \times 100$$

### 3.5.4 Determination of protein content

**Principle**

Protein content can be measured by estimating the nitrogen content of the material and then multiplying the nitrogen value by 6.25. This is referred to as crude protein content, since the non-protein (NPN) present in the materials was taken into consideration in the present investigation. The estimation of nitrogen was made by modified Kjeldahl method (Ranganna S, 1992), which depends on the fact that organic nitrogen, when digested with concentrated sulphuric acid ($H_2SO_4$). In the presence of a catalyst, is converted into ammonium sulphate $(NH_4)_2SO_4$. Alkali is added to the sample to convert ammonium ($NH_4^+$) to ammonia ($NH_3$). The ammonia is steam distilled into a receiver flask containing boric acid and titrated with a standard acid solution. This determines % of N that is multiplied by 6.25 to give the value of crude protein.

**Digestion Mixture**

Potassium sulphate ($K_2SO_4$) and dehydrated copper sulphate ($CuSO_4.5H_2O$) in a ratio of 5g: 1g were powdered with mortar and pestle and mixed well. Concentrated HCl was used for titration.

**Sodium hydroxide (40%)**

Sodium hydroxide (NaOH) 40 gm was dissolved in distilled water and the volume was made up to 100 ml.

**Receiver Solution**

10g of boric acid was added in 500 ml deionized water in a one liter volumetric flask, heated it gently until the boric acid was dissolved. An amount of 0.02 g bromo cresol green was dissolved with 4 ml ethanol ($C_2H_5OH$) in a separate beaker. An amount of 0.014g methyl red was dissolved with 4 ml ethanol ($C_2H_5OH$) in another beaker. Some bromo cresol green and methyl red solution mixture was than transferred into that volumetric flask and 0.5 ml 1N NaOH was added when the total volume was made 1000 ml with deionized water.

**Procedure**

The Kjeldahl method consists of the following steps:

- Digestion of the sample
- Distillation
- Titration

**Digestion of the sample**

The sample (10g) was taken in weighing paper and measured accurately. This sample was poured into a 100 ml clean and dry Kjeldahl flask, to which 10 gm of Digestion Mixture and 25 ml of concentrated HCl were added. To avoid frothing and bumping 2-5 glass beads was placed inside the flask. A blank was carried with all reagents except sample material for the comparison. The flask was then heated in a Fume hood Digestion chamber at 400°C until the solution became colorless. At the end of digestion period, the flasks were cooled and diluted with 100 ml distilled water. A small piece of litmus paper was placed in the solution and the reaction was found to be acidic.

**Distillation**

The distilling set of Kjeldahl apparatus was thoroughly washed with distilled water before starting the distillation. In a measuring cylinder 60 ml of 40% NaOH was taken and it was carefully poured down the side of the Kjeldahl flask. The mouth of the flask was closed with a stopper containing connective tube, which was ultimately connected to the ammonia-receiving flask containing 25 ml receiver solution.

The mixture was boiled at such a rate that water and ammonia distilled over at a steady moderate rate. The heating was not too slow so that the receiver solution might be sucked into the Kjeldahl flask and not to fast so that the distilling ammonia did not escape the receiver solution without absorption.

**Titration**

The ammonia absorbed in the receiving flask containing receiver solution was titrated with 0.1 N HCl. Similarly a reagent blank was distilled and titrated.

**Calculation**

Protein content of the sample on the percentage basis was calculated by the following formula:

$$\% \text{ of protein (g)} = \frac{(c-b)\times 14\times d\times 6.25}{a}\times 100$$

Where,

a = sample weight (g)

b = volume of the sodium hydroxide required for the back titration

c = volume of sodium hydroxide required for the back and to neutralize 20 ml of 0.1 N $H_2SO_4$ (for blank)

d = Normality of NaOH used for titration.

The conversion factor of nitrogen to protein is 6.25 and atomic weight of nitrogen is 14.

### 3.5.5 Total Carbohydrate

The total carbohydrate content of the samples was determined as total carbohydrate by difference, which is by subtracting the measured moisture, ash, fat and protein from 100(Pearson, 1970).

### 3.5.6 Determination of K, Ca, Mg, Zn, Fe and P

Organic matter is digested and K, Ca, Mg, Zn, Fe and P are released by digestion with nitric and perchloric acid. Ca, Mg, Zn and Fe are determined by atomic absorption spectrophotometry, K is determined by flame photometry, and P is determined by spectrophotometry and each element was determined separately for each sample.

**Digestion**

**a)** 0.5g of banana powder was weighted into a 200ml conical flask. Add 20ml 68% nitric acid and 10ml 70% prechloric acid (2:1) to the conical flask. Then the conical flask was placed in the digestion chamber on an adjustable heater and covered with the exhaust manifold. The temperature was set at 125°C and allowed to boil until the brown smoke become white and a clear solution obtained also observed that conical flask do not become dry. If the flask becomes dry add another 10ml solution (2:1) of 68% nitric acid and 10ml 70% prechloric acid.

**b)** After cooling, the digestion mixture was transferred to a 100ml volumetric flask. Made the flask to volume with distilled water and mixed. Filtered on a dry filter into a dry bottle, which could be closed with a screw cap. The filtrate was kept in the closed bottle. K, Ca, Mg, Zn, Fe and P were determined in the filtrate.

**3.5.6.1 Determination of Ca, Mg, K and P:**

i) Using a pipette, 20ml filtrate was transferred into a100ml volumetric flask. Made the flask to volume with distilled water and mixed.

ii) Measurement of Ca

20ml diluted filtrate was transferred into a 50ml volumetric flask using a pipette. 5ml $LaCl_3$ solution was added and made the volume with distilled water and mixed. The content of Ca was measured by atomic absorption spectrometer (AAS). If the reading is higher than the reading of the highest standard solution, we have to make a larger dilution, e.g. 10ml filtrate into a50ml volumetric flask. In this case 1:100 diluted $HNO_3$ must be added to the volumetric flask to make the total volume of 1:100 diluted $HNO_3$and filtrate equal to 20ml.

iii) Measurement of Mg

5ml diluted filtrate was transferred into a 50ml volumetric flask using a pipette. 5ml $LaCl_3$ solution was added and made the volume with distilled water and mixed. The content of Mg was measured by atomic absorption spectrophotometer (AAS). If the reading is higher than the reading of the highest standard solution, we have to make a larger dilution, e.g. 2ml filtrate into a50ml volumetric flask. In this case 1:100 diluted $HNO_3$ must be added to the volumetric flask to make the total volume of 1:100 diluted $HNO_3$and filtrate equal to 5ml.

iv) Measurement of K

10ml diluted filtrate was transferred into a 50ml volumetric flask using a pipette. 5ml $LaCl_3$ solution was added and made the volume with distilled water and mixed. The content of K was measured by flame photometer. If the reading is higher than the reading of the highest standard solution, we have to make a larger dilution, e.g. 5ml filtrate into a 50ml volumetric flask. In this case 1:100 diluted $HNO_3$ must be added to the volumetric flask to make the total volume of 1:100 diluted $HNO_3$ and filtrate equal to 10ml.

v) Measurement of P

5ml diluted filtrate was transferred into a 50ml volumetric flask using a pipette. 30ml distilled water and 10ml ammonium molybdate-ascorbic acid solution were added, made to volume with distilled water and mixed. After 15 minutes the absorbance was measured on a spectrophotometer at 890nm. If the absorbance is higher than that of the, repeat the procedure using a smaller amount of filtrate. In this case 1:100 diluted $HNO_3$ must be added to the volumetric flask to make the total volume of 1:100 diluted $HNO_3$ and filtrate equal to 5ml.

If the content of P is very high, it is necessary to dilute the filtrate further before the transfer to the 50ml flask. The dilution is made with water using pipette and volumetric flask. After transfer of 5ml diluted filtrate to the 50ml volumetric flask, 5ml 1:100 diluted $HNO_3$ and water to 30mlare added. Then 10ml ammonium molybdate-ascorbic acid is added, the 50ml volumetric flask is made to volume with water and the absorbance is measured on a spectrophotometer at 890nm after 15 minutes.

**Calculations for Ca, Mg, K and P**

$$\text{mg per Kg plant material} = \frac{a \times 2500}{b \times c}$$

Where,

a = mg/l Ca, Mg, K or P measured on atomic absorption spectrophotometer, flame photometer or spectrophotometer.

b = ml diluted filtrate transferred into the 50ml volumetric flask for determination of Ca, Mg, K and P.

c = g plant material weighted into the digestion flask.

### 3.5.6.2 Determination of Zn and Fe

The contents of these elements were measured by atomic absorption spectrophotometer (AAS) directly in the undiluted filtrate.

**Calculations for Zn and Fe :**

$$\text{mg per Kg plant material} = \frac{d \times 100}{c}$$

Where,

d = mg/l Zn or Fe measured on atomic absorption spectrometer or spectrophotometer.

c = g plant material weighted into the digestion flask

### 3.6 Statistical Analysis

The data for the characters of the present study were statistically analyzed wherever applicable. The experiments were conducted one factor Completely Randomized Design (CRD). The analyses of variance (ANOVA) for different characters were performed with the help of a computer program MSTAT-C and means were compared by the Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984). The standard error of each sample at different periods was also analyzed by MS Office Excel (2007).

# CHAPTER IV
# RESULTS AND DISCUSSION

# CHAPTER IV

# RESULT AND DISCUSSION

## 4.1 Composition of fresh banana pulp

The fresh banana pulp was analyzed for moisture, ash, fat, protein, total carbohydrate and mineral contents (K, Ca, Mg, Zn, Fe and P). The results are shown in Table 4.1. The banana pulp contains 70.75g moisture, 0.97g protein, 0.43g fat, 0.85g ash, 27g total carbohydrate, 135.72mg potassium, 13.37mg calcium, 31.46mg magnesium, 0.178mg zinc, 0.491mg iron and 25.34mg phosphorus per 100g. The results were more or less similar to those reported by Dickson (2000) and Edinformatics (2006) and showed in Table 2.2 and Table 2.3.

**Table 4.1 Composition of banana pulp**

| **Parameter** | **Banana** |
|---|---|
| Moisture | 70.75g/100g |
| Protein | 0.97g/100g |
| Fat | 0.43g/100g |
| Ash | 0.85g/100g |
| Total Carbohydrate | 27g/100g |
| Potassium | 135.72mg/100g |
| Calcium | 13.37mg/100g |
| Magnesium | 31.46mg/100g |
| Zinc | 0.178mg/100g |
| Iron | 0.491mg/100g |
| Phosphorus | 25.34mg/100g |

**Fig 4.1 Fresh Ripe Amritasagar Variety of Banana**


**Fig 4.2 Dried Banana Chips Before Grinding**


**Fig 4.3 Grinded Banana Powder**


**Fig 4.4 Banana Powder Stored in Single Layer High Density Polyethylene**

### 4.2 Yield of banana powder

The yields of banana powder were determined for four samples. The 1st sample was pretreatment free (control sample); the 2nd sample was treated with citric acid; the 3rd sample was treated with potassium metabisulphate (KMS) and the 4th sample was treated with both citric acid and potassium metabisulphate (KMS). The results are shown in Table 4.2. The table 4.2 showed that the yield of banana powder is more or less same for all four samples (both untreated and treated). So there is no significant effect of pretreatment on the yield of banana powder.

**Table 4.2 Yield of banana powder**

| Samples | Yield (g powder/100g pulp) |
|---|---|
| Sample 1 | 29.25 |
| Sample 2 | 29.58 |
| Sample 3 | 29.69 |
| Sample 4 | 29.86 |

### 4.3 Storage studies of banana powder

#### 4.3.1 Physical properties of banana powder

Water holding capacity (WHC) and oil holding capacity (OHC) are the two physical properties which are only studied in this research work. Good water holding property implies the potentials of banana flour to be used as a thickener in liquid and semi liquid foods and Good oil absorption capacities of the flours suggest that they may be useful in food preparations that involve oil mixing, such as in bakery products where oil is an important ingredient.

##### 4.3.1.1 Water holding capacity (WHC)

The mean water holding capacity of each sample from zero (0) to 180 days at each period finally ranged between 2.27- 3.79g/g dry sample (Appendix 1). These values are lower than those reported in mango dietary fiber (12 and 15 g water/g dry sample) and mango

peel dietary fiber (11 g/g) (Larrauri *et al.,* 1996), but were similar to those of fiber-rich unripe banana flour (2.5 g/g) (Rodriguez *et al.,* 2008). WHC could be related to the physical state of starch (Waliszewski *et al.*, 2003), dietary fiber and protein in the flour. It was the release of amylose which has the capacity to effectively bind water molecules that yielded a higher WHC (Rodriguez *et al.*, 2008). Starch however is not the principal component of ripe banana (Zhang *et al.*, 2005), leaving dietary fibers and protein as the main contributing factors that influence WHC of ripe banana powder. The change in WHC (decrease with period) of banana powder is shown in figure 4.5.

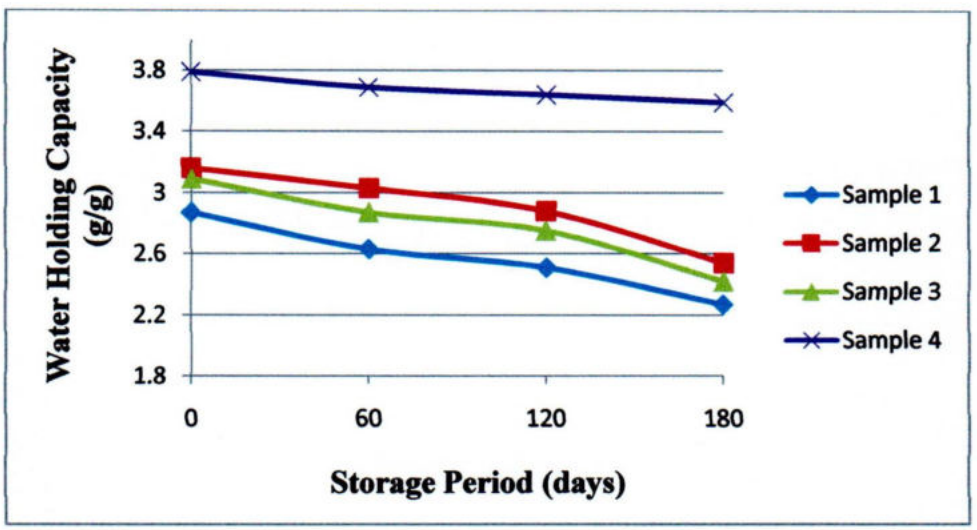


**Fig. 4.5 Pretreatment effect on the water holding capacity of banana powder during storage**

A one way analysis of variance (ANOVA) (Appendix 2) was carried out for WHC of samples and results revealed that there were significant ($p<0.05$) differences in WHC among the samples. This indicates that the WHC of different samples of banana powder were not equally acceptable. As shown in appendix 3 (DMRT) the sample 4 is secured the highest value for WHC than other samples. However, sample 2 and 3 secured more or less equal value and sample 1 secured the lowest value. The mean values from appendix 3 (DMRT) are shown in figure 4.6. From the figure 4.6 we can conclude that sample 4 has the highest WHC, also decrease in WHC of the samples (Appendix 1) 1, 2, 3 and 4 from zero (0) to 180 days are 0.6g/g, 0.62g/g, 0.67g/g and 0.20g/g dry sample respectively. Here the change in WHC of sample 4 is lowest. So sample 4 is more acceptable compared to other samples.

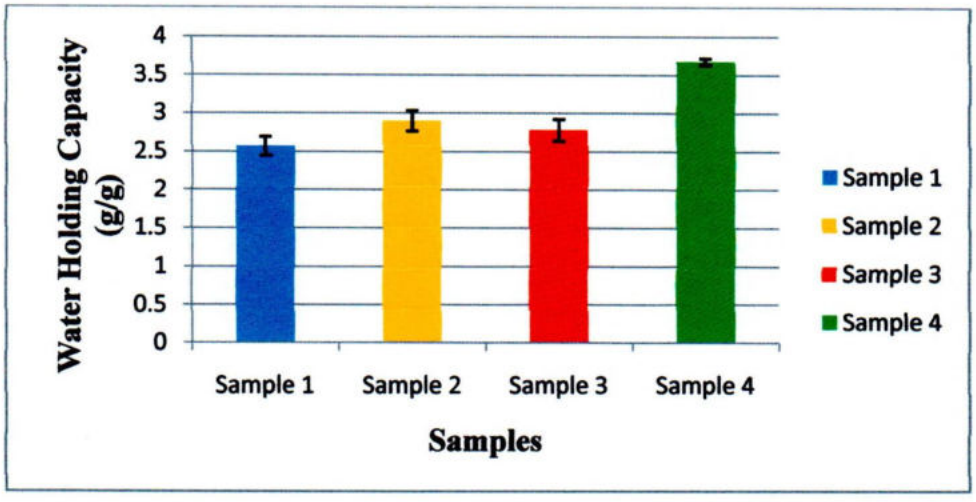


**Fig 4.6 Water holding capacity (WHC) of banana powder based on mean score**

### 4.3.1.2 Oil Holding Capacity

The mean oil holding capacity of each sample from zero (0) to 180 days at each period finally ranged between 0.72- 1.08g/g dry sample (Appendix 4). These values are slightly lower than that reported in fiber-rich banana powder that could hold 2.2 g oil/g dry sample (Rodriguez *et al.,* 2008), but are similar to that of mango dietary fiber with OHC in the range 1.0 – 1.5 g oil/g (Larrauri *et al.,* 1996). OHC relates to the hydrophilic character of starches present in the powder (Rodriguez *et al.,* 2008) that could be present in some quantity in Amritsagar banana powder. The change in OHC (decrease with period) of banana powder is shown in figure 4.7.

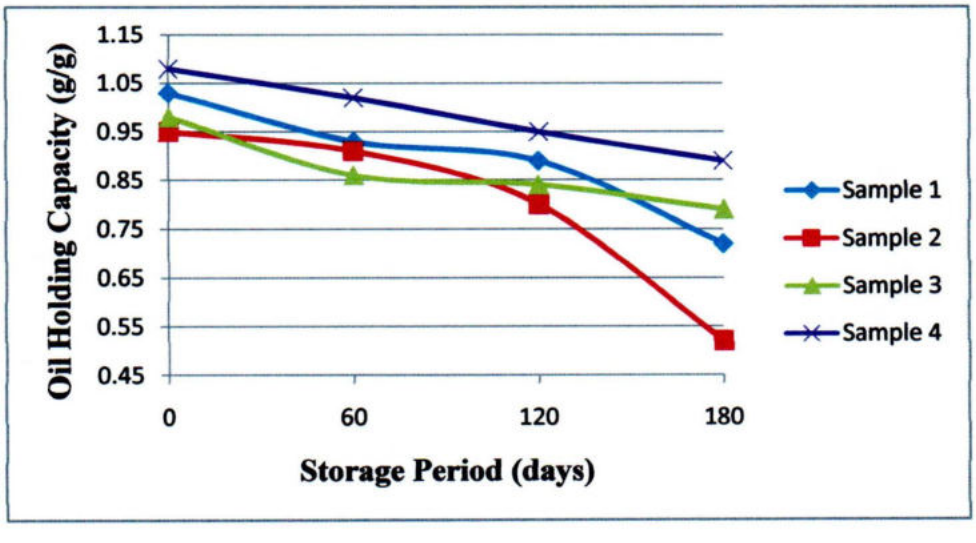


**Fig. 4.7 Pretreatment effect on the oil holding capacity of banana powder during storage**

A one way analysis of variance (ANOVA) (Appendix 5) was carried out for OHC of samples and results revealed that there were significant ($p<0.05$) differences in OHC among the samples. This indicates that the OHC of different samples of banana powder were not equally acceptable. As shown in appendix 6 (DMRT) the sample 4 is secured the highest value for OHC than other samples. However, the value of sample 2 and 3 were equally acceptable and sample 1 secured more than 2 and 3 but less than sample 1. The mean values from appendix 6 (DMRT) are shown in figure 4.8. From the figure 4.8 we can conclude that sample 4 has the highest OHC, also decrease in OHC of the samples (Appendix 4) 1, 2, 3 and 4 from zero (0) to 180 days are 0.31g/g, 0.43g/g, 0.19g/g and 0.19g/g dry sample respectively. Here the decrease in OHC of sample 4 and 3 are lowest. So sample 4 is more acceptable compared to other samples.

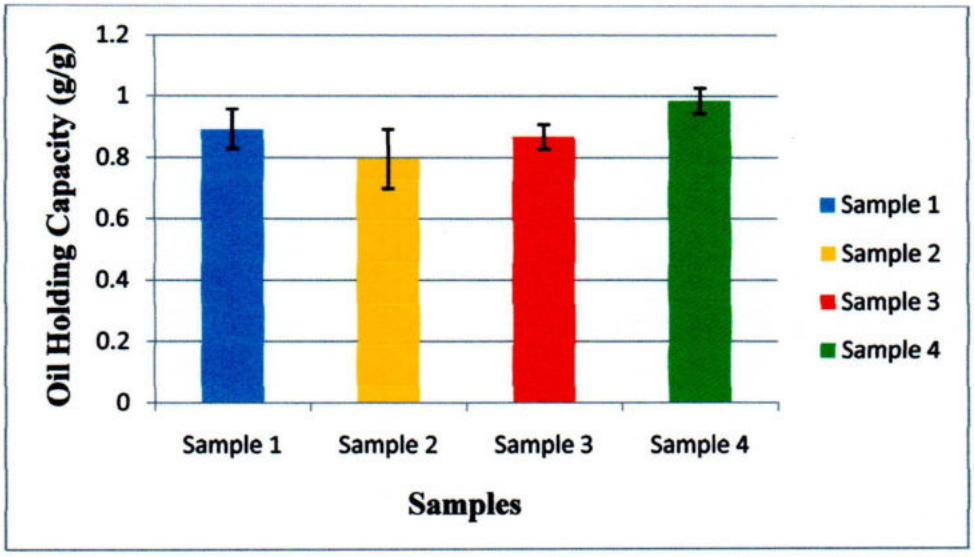


**Fig 4.8 Oil holding capacity (OHC) of banana powder based on mean score**

### 4.3.2 Chemical properties of banana powder

#### 4.3.2.1 Moisture content of banana powder

The mean moisture content of each sample from zero (0) to 180 days at each period finally ranged between 4.29- 11.52g/100g dry sample (Appendix 7). At the end of 180 days sample 4 has the lowest moisture content, which was similar to Selvamani (2009) and sample 1 has the highest value which is similar to Islam (2012). Milled products with low moisture content of less than 13 % are stable from moisture dependent deterioration (Potter and Hotchkiss, 1995). The change in moisture content (increase with period) of banana powder is shown in figure 4.9.

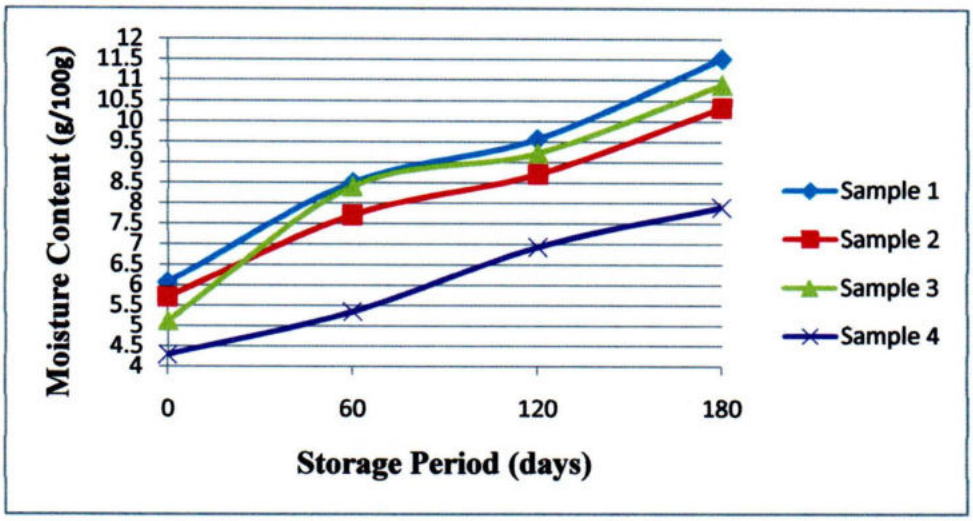


**Fig. 4.9 Pretreatment effect on the moisture content of banana powder during storage**

A one way analysis of variance (ANOVA) (Appendix 8) was carried out for MC of samples and results revealed that there were significant ($p<0.05$) differences in MC among the samples. This indicates that the MC of different samples of banana powder was not equally acceptable. As shown in appendix 9 (DMRT) the sample 1 is secured the highest value for MC than other samples. Sample 3 is in between 2 and 1 but sample 4 has the lowest value. The mean values from appendix 9 (DMRT) are shown in figure 4.10. From the figure 4.10 we can conclude that sample 4 has the lowest MC, also increase in MC of the samples (Appendix 7) 1, 2, 3 and 4 from zero (0) to 180 days are 5.45g/100g, 4.62g/100g, 5.77g/100g and 3.61g/100g dry sample respectively. Here the increase in MC of sample 4 is lowest. So sample 4 is more acceptable compared to other samples.

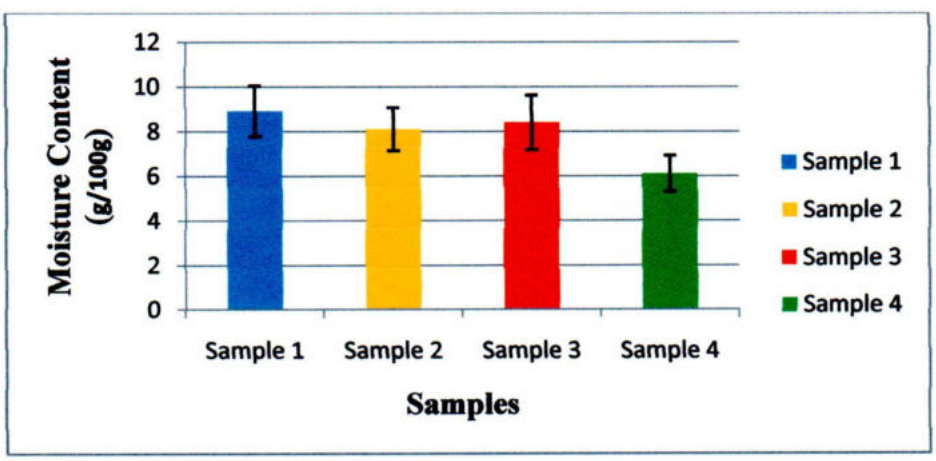


**Fig 4.10 Moisture content of banana powder based on mean score**

### 4.3.2.2 Ash content of banana powder

The mean ash content of each sample from zero (0) to 180 days at each period finally ranged between 2.34- 4.10g/100g dry sample (Appendix 10). These values are similar to Islam (2012) but less than Juarez *et al.* (2006) and Suntharalingham and Ravindran (1993). The ash content reflects the presence of minerals. The change in ash content (increase with period) of banana powder is shown in figure 4.11.

A one way analysis of variance (ANOVA) (Appendix 11) was carried out for ash content of samples and results revealed that there were significant ($p<0.05$) differences in ash content among the samples. This indicates that the ash content of different samples of banana powder was not equally acceptable. As shown in appendix 12 (DMRT) the sample 1 is secured the highest value for ash content than other samples. But Sample 1 and 3 are equally acceptable and sample 4 has the lowest value. The mean values from appendix 12 (DMRT) are shown in figure 4.12. From the figure 4.12 we can conclude that sample 4 has the lowest ash content, also increase in ash content of the samples (Appendix 10) 1, 2, 3 and 4 from zero (0) to 180 days are 0.92g/100g, 1.21g/100g, 1.27g/100g and 0.38g/100g dry sample respectively. Here the increase in ash content of sample 4 is lowest.

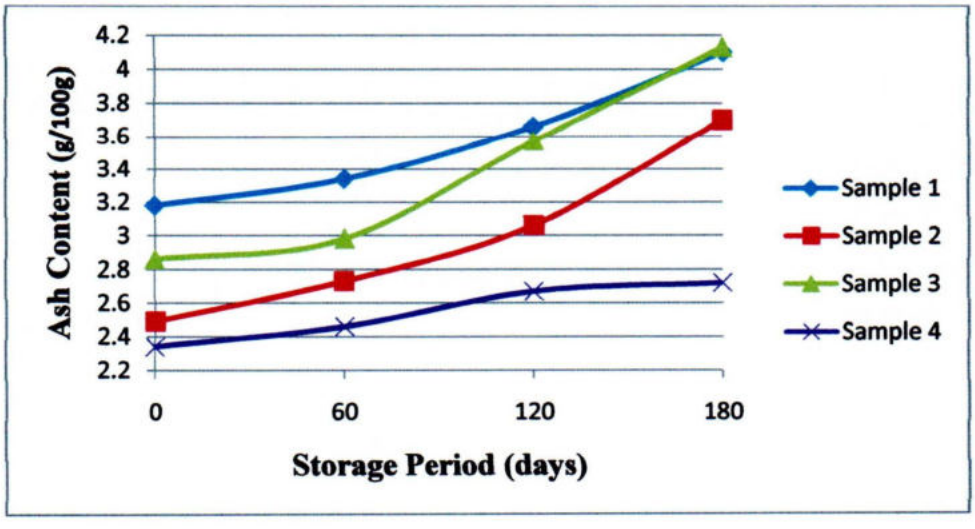


**Fig. 4.11 Pretreatment effect on the ash content of banana powder during storage**

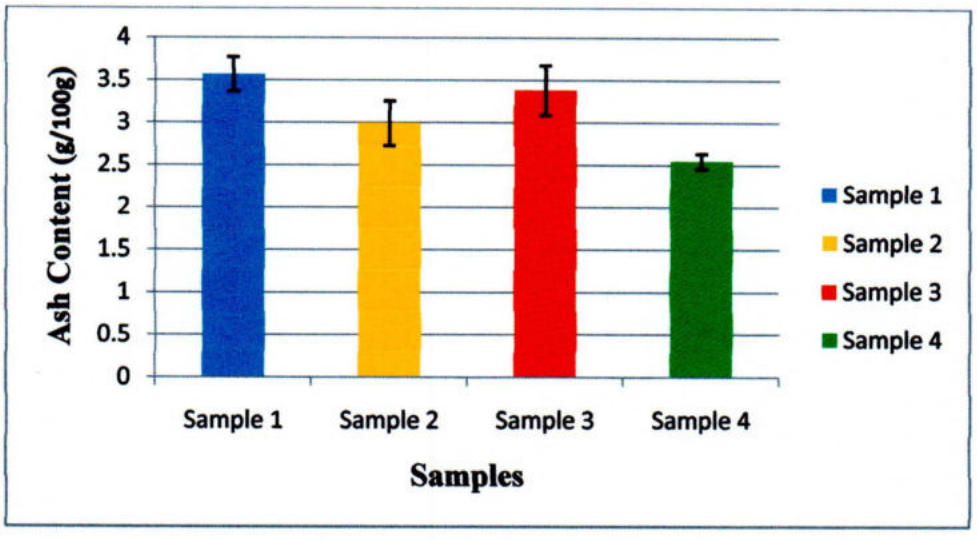


**Fig 4.12 Ash content of banana powder based on mean score**

### 4.3.2.3 Protein content of banana powder

The mean protein content of each sample from zero (0) to 180 days at each period finally ranged between 1.32- 3.20g/100g dry sample (Appendix 13). At the end of 180 days sample 1 has lowest protein content, which is similar to Selvamani (2009) and sample 4 has the highest protein content, which is similar to Islam (2012). The change in protein content (decrease with period) of banana powder is shown in figure 4.13.

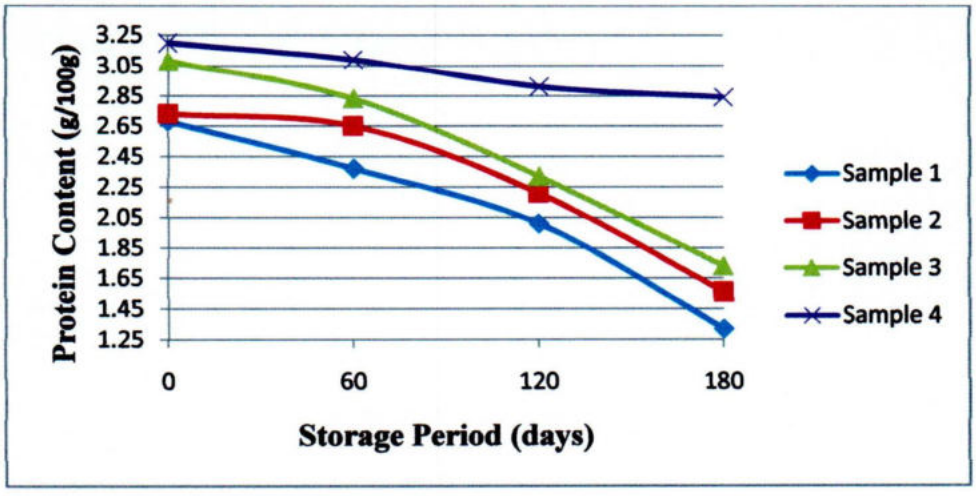


**Fig. 4.13 Pretreatment effect on the protein content of banana powder during storage**

A one way analysis of variance (ANOVA) (Appendix 14) was carried out for protein content of samples and results revealed that there were significant ($p<0.05$) differences in

protein content among the samples. This indicates that the protein content of different samples of banana powder was not equally acceptable. As shown in appendix 15 (DMRT) the sample 4 is secured the highest value for protein content than other samples and sample 1 has the lowest value. But sample 2 is in between 3 and 1. The mean values from appendix 15 (DMRT) are shown in figure 4.14. From the figure 4.14 we can conclude that sample 4 has the highest protein content, also decrease in protein content of the samples (Appendix 13) 1, 2, 3 and 4 from zero (0) to 180 days are 1.36g/100g, 1.17g/100g, 1.35g/100g and 0.36g/100g dry sample respectively. Here the decrease in protein content of sample 4 is lowest. So sample 4 is more acceptable compared to other samples.

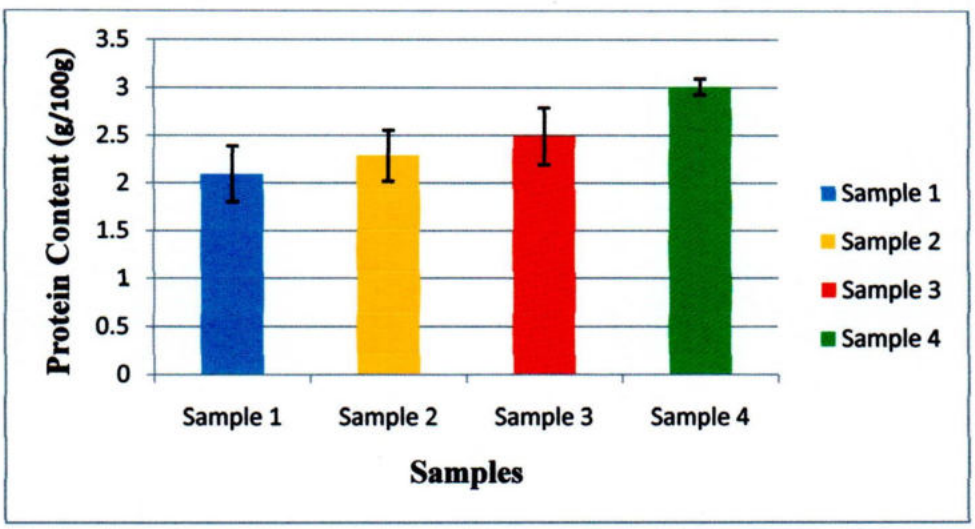


**Fig 4.14 Protein content of banana powder based on mean score**

#### 4.3.2.4 Fat content of banana powder

The mean fat content of each sample from zero (0) to 180 days at each period finally ranged between 0.30- 0.77g/100g dry sample (Appendix 16). At the end of 180 days sample 1 has lowest fat content, which is similar to Selvamani (2009) and sample 4 has the highest fat content, which is less than Islam (2012). The change in fat content (decrease with period) of banana powder is shown in figure 4.15.

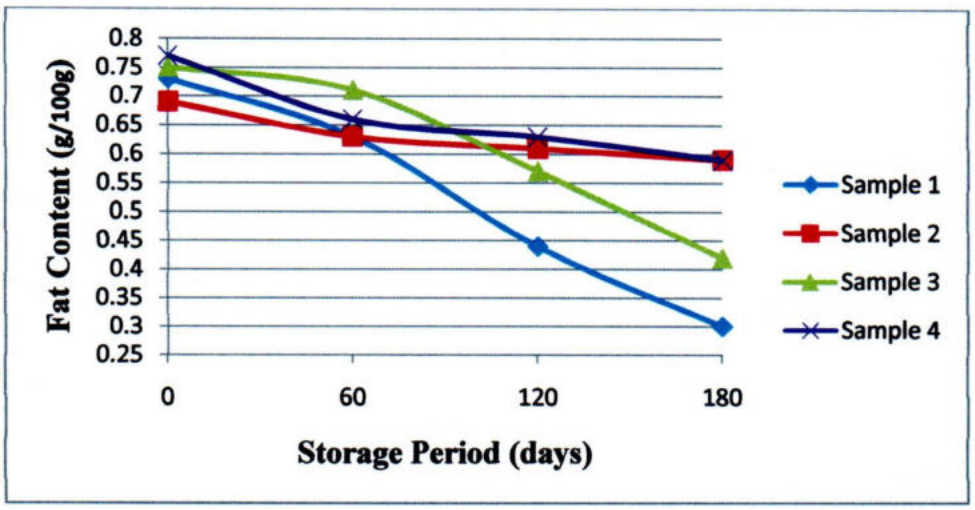


**Fig. 4.15 Pretreatment effect on the fat content of banana powder during storage**

A one way analysis of variance (ANOVA) (Appendix 17) was carried out for fat content of samples and results revealed that there were significant ($p<0.05$) differences in fat content among the samples. This indicates that the fat content of different samples of banana powder was not equally acceptable. As shown in appendix 18 (DMRT) the sample 4 is secured the highest value for fat content than other samples and sample 1 has the lowest value. But sample 2 and sample 3 have same level of acceptance. The mean values from appendix 18 (DMRT) are shown in figure 4.16. From the figure 4.16 we can conclude that sample 4 has the highest fat content, also decrease in fat content of the samples (Appendix 16) 1, 2, 3 and 4 from zero (0) to 180 days are 0.43g/100g, 0.1g/100g, 0.33g/100g and 0.18g/100g dry sample respectively. Here the decrease in fat content of sample 2 is lowest, but finally the total fat content is higher than sample 2. So sample 4 is more acceptable compared to other samples.

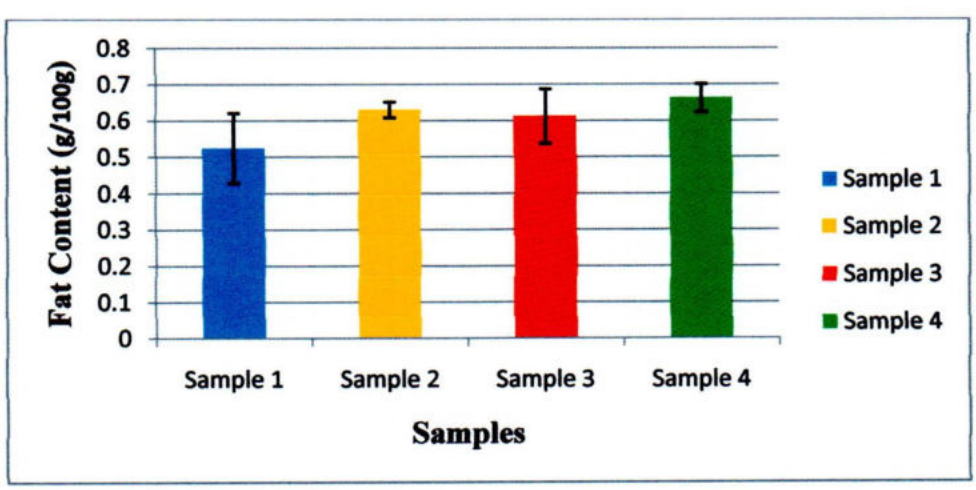


**Fig 4.16 Fat content of banana powder based on mean score**

### 4.3.2.5 Total carbohydrate content of banana powder

The mean total carbohydrate content of each sample from zero (0) to 180 days at each period finally ranged between 82.76- 89.44g/100g dry sample (Appendix 19). At the end of 180 days sample 1 has lowest protein content, which is similar to Selvamani (2009) and sample 4 has the highest protein content, which is less than Islam (2012). The change in total carbohydrate content (decrease with period) of banana powder is shown in figure 4.17.

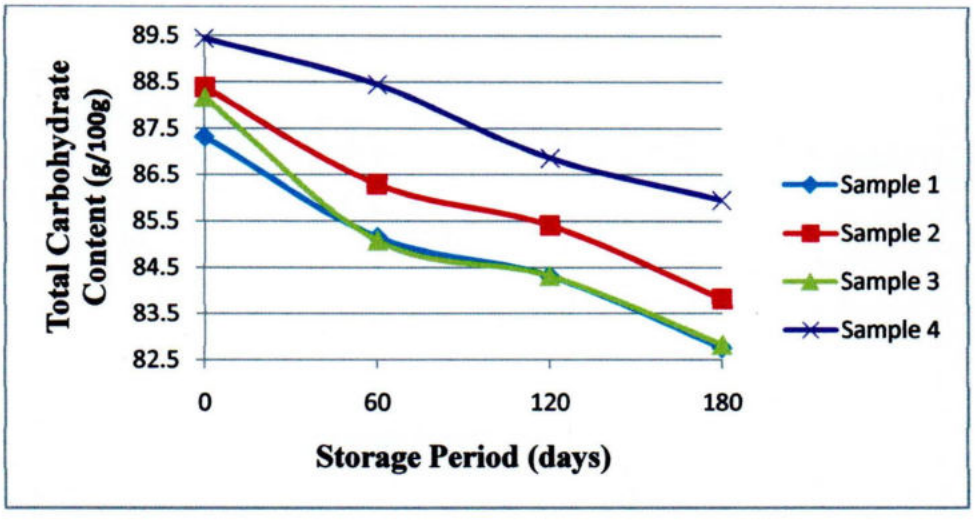


**Fig. 4.17 Pretreatment effect on the total carbohydrate content of banana powder during storage**

A one way analysis of variance (ANOVA) (Appendix 20) was carried out for total carbohydrate content of samples and results revealed that there were significant ($p<0.05$) differences in fat content among the samples. This indicates that the total carbohydrate content of different samples of banana powder was not equally acceptable. As shown in appendix 21 (DMRT) the sample 4 is secured the highest value for total carbohydrate content than other samples and sample 1 has the lowest value. But sample 1 and sample 3 have same level of acceptance. The mean values from appendix 21 (DMRT) are shown in figure 4.18. From the figure 4.18 we can conclude that sample 4 has the highest total carbohydrate content, also decrease in total carbohydrate content of the samples (Appendix 19) 1, 2, 3 and 4 from zero (0) to 180 days are 4.56g/100g, 4.56g/100g, 5.34g/100g and 3.49g/100g dry sample respectively. Here the decrease in total carbohydrate content of sample 4 is lowest. So sample 4 is more acceptable compared to other samples.

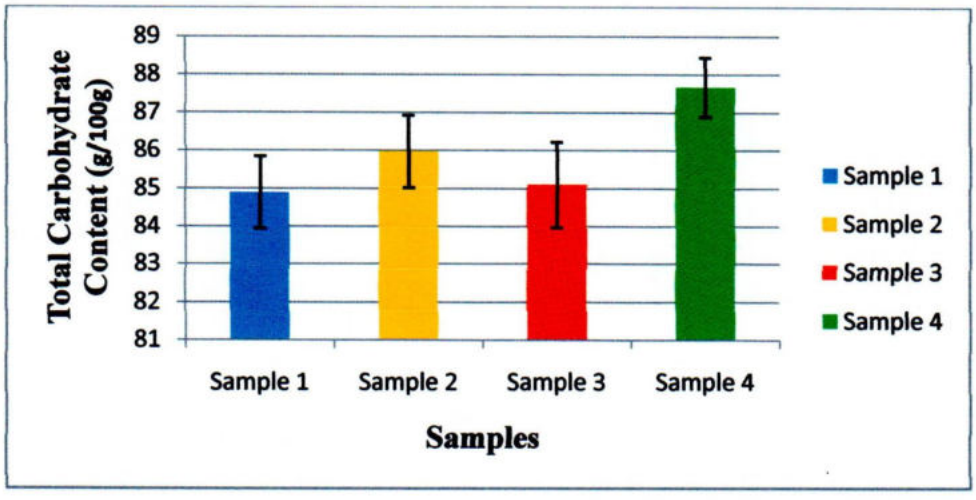


**Fig 4.18 Total carbohydrate content of banana powder based on mean score**

#### 4.3.2.6 Potassium content of banana powder

The mean potassium content of each sample from zero (0) to 180 days at each period finally ranged between 324.27- 325mg/100g dry sample (Appendix 22). All the values are less than Abbas *et al.*, (2009). The change in potassium content of banana powder is shown in figure 4.19.

A one way analysis of variance (ANOVA) (Appendix 23) was carried out for potassium content of samples and results revealed that there were significant ($p<0.05$) differences in potassium content among the samples. This indicates that the potassium content of different samples of banana powder was not equally acceptable. As shown in appendix 24 (DMRT) the sample 4 is secured the highest value for potassium content than other samples and sample 1 has the lowest value. But sample 4 and sample 3 have same level of acceptance. The mean values from appendix 24 (DMRT) are shown in figure 4.20. From the figure 4.20 we can conclude that sample 4 has the highest potassium content, also change in potassium content of the samples (Appendix 22; decrease of sample 1& 2 and increase of sample 3 & 4) 1, 2, 3 and 4 from zero (0) to 180 days are 0.73mg/100g, 0.32mg/100g, 0.21mg/100g and 0.38mg/100g dry sample respectively. Here the change in potassium content of sample 3 is lowest but finally the potassium content of sample 4 is highest. Therefore sample 4 is more acceptable compared to other samples.

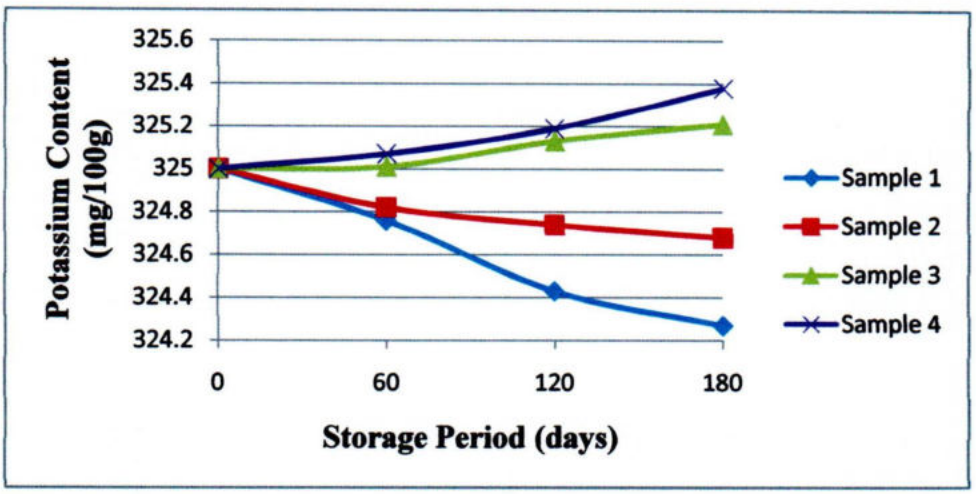


**Fig. 4.19 Pretreatment effect on the potassium content of banana powder during storage**

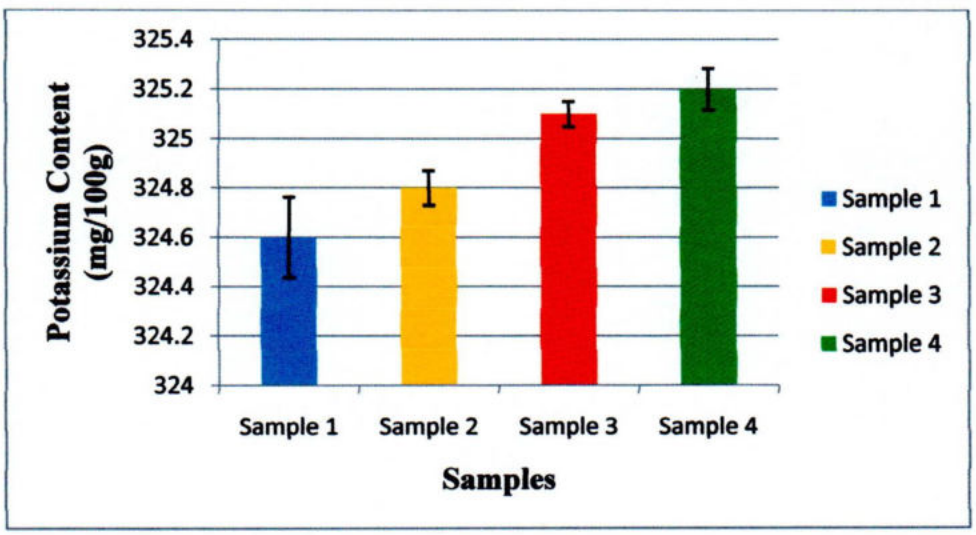


**Fig 4.20 Potassium content of banana powder based on mean score**

### 4.3.2.7 Calcium content of banana powder

The mean calcium content of each sample from zero (0) to 180 days at each period finally ranged between 54.69- 58.41mg/100g dry sample (Appendix 25). All the values are higher than Abbas *et al.*, (2009). The change in calcium content of banana powder is shown in figure 4.21.

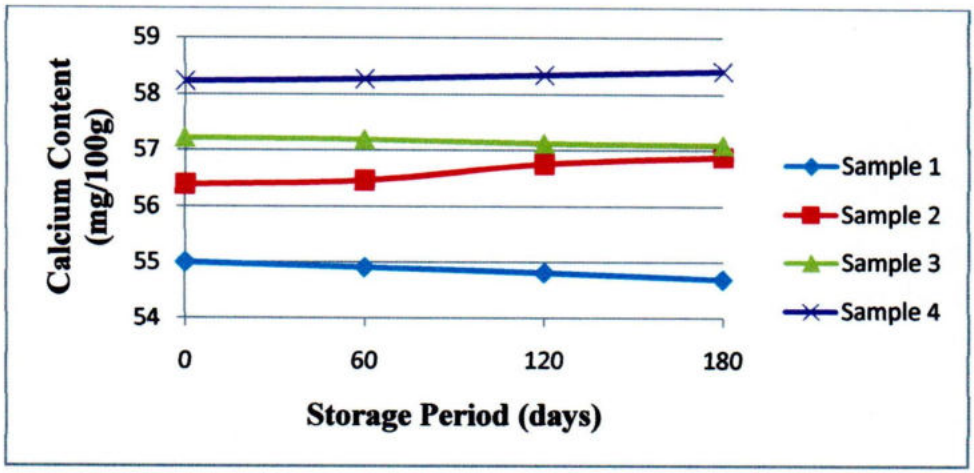


**Fig. 4.21 Pretreatment effect on the calcium content of banana powder during storage**

A one way analysis of variance (ANOVA) (Appendix 26) was carried out for calcium content of samples and results revealed that there were significant ($p<0.05$) differences in calcium content among the samples. This indicates that the calcium content of different samples of banana powder was not equally acceptable. As shown in appendix 27 (DMRT) the sample 4 is secured the highest value for calcium content than other samples and sample 1 has the lowest value. The mean values from appendix 27 (DMRT) are shown in figure 4.22. From the figure 4.22 we can conclude that sample 4 has the highest calcium content, also change in calcium content of the samples (Appendix 25; decrease of sample 1 and increase of sample 2, 3 & 4) 1, 2, 3 and 4 from zero (0) to 180 days are 0.41mg/100g, 0.49mg/100g, 0.13mg/100g and 0.18mg/100g dry sample respectively. Here the change in calcium content of sample 3 is lowest but finally the calcium content of sample 4 is highest. Therefore sample 4 is more acceptable compared to other samples.

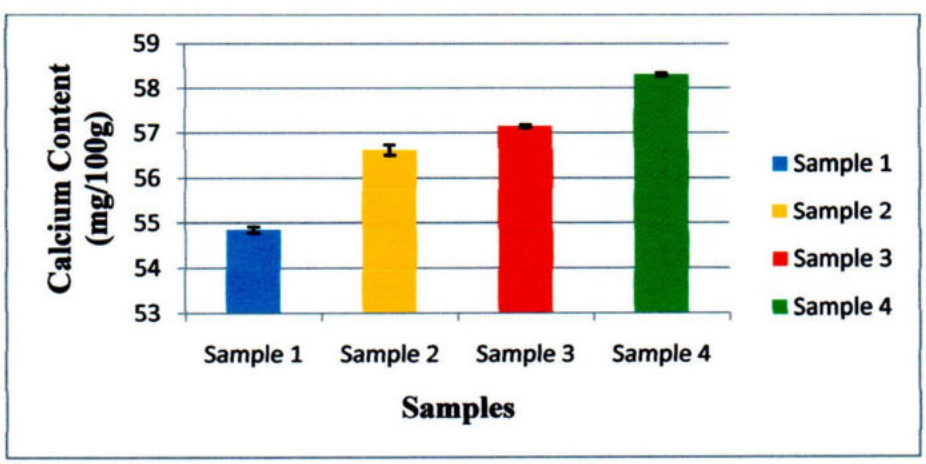


**Fig 4.22 Calcium content of banana powder based on mean score**

### 4.3.2.8 Magnesium content of banana powder

The mean magnesium content of each sample from zero (0) to 180 days at each period finally ranged between 145.0- 148.5mg/100g dry sample (Appendix 28). All the values are higher than Abbas *et al.*, (2009). The change in magnesium content of banana powder is shown in figure 4.23.

A one way analysis of variance (ANOVA) (Appendix 29) was carried out for magnesium content of samples and results revealed that there were significant ($p<0.05$) differences in magnesium content among the samples. This indicates that the magnesium content of different samples of banana powder was not equally acceptable. As shown in appendix 30 (DMRT) the sample 4 secured the highest value for magnesium content than other samples and sample 1 has the lowest value. The mean values from appendix 30 (DMRT) are shown in figure 4.24. From the figure 4.24 we can conclude that sample 4 has the highest magnesium content, also change in magnesium content of the samples (Appendix 28; decrease of sample 4, increase of sample 2, 3 and sample 1 remain constant) 1, 2, 3 and 4 from zero (0) to 180 days are 0.00mg/100g, 0.30mg/100g, 0.23mg/100g and 0.06mg/100g dry sample respectively. Here the change in magnesium content of sample 4 is lowest but finally the magnesium content of sample 4 is highest. Therefore sample 4 is more acceptable compared to other samples.

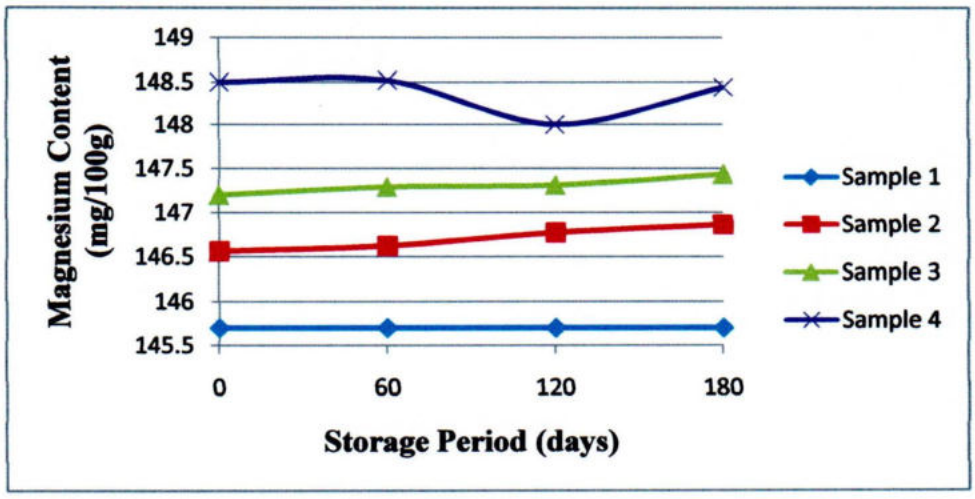


**Fig. 4.23 Pretreatment effect on the magnesium content of banana powder during storage**

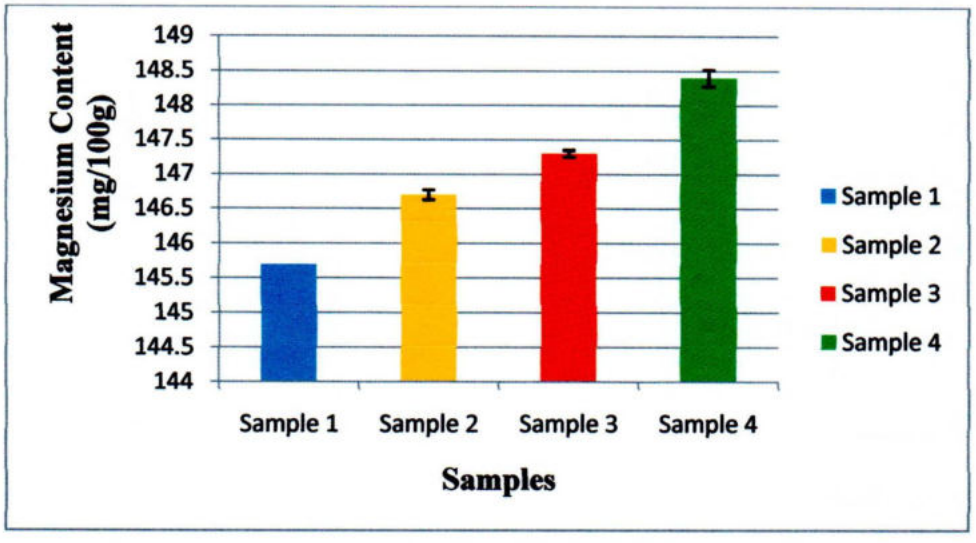


**Fig 4.24 Magnesium content of banana powder based on mean score**

### 4.3.2.9 Zinc content of banana powder

The mean zinc content of each sample from zero (0) to 180 days at each period finally ranged between 2.10- 2.69mg/100g dry sample (Appendix 31). All the values are higher than Abbas *et al.*, (2009). The change in zinc content of banana powder is shown in figure 4.25.

A one way analysis of variance (ANOVA) (Appendix 32) was carried out for zinc content of samples and results revealed that there were significant ($p<0.05$) differences in zinc content among the samples. This indicates that the zinc content of different samples of banana powder was not equally acceptable. As shown in appendix 33 (DMRT) the sample 4 secured the highest value for zinc content than other samples and sample 2 has the lowest value. The mean values from appendix 33 (DMRT) are shown in figure 4.26. From the figure 4.26 we can conclude that sample 4 has the highest zinc content, also change in zinc content of the samples (Appendix 31; decrease of all samples) 1, 2, 3 and 4 from zero (0) to 180 days are 0.15mg/100g, 0.07mg/100g, 0.15mg/100g and 0.09mg/100g dry sample respectively. Here the change in zinc content of sample 2 is lowest but finally the zinc content of sample 4 is highest. Therefore sample 4 is more acceptable compared to other samples.

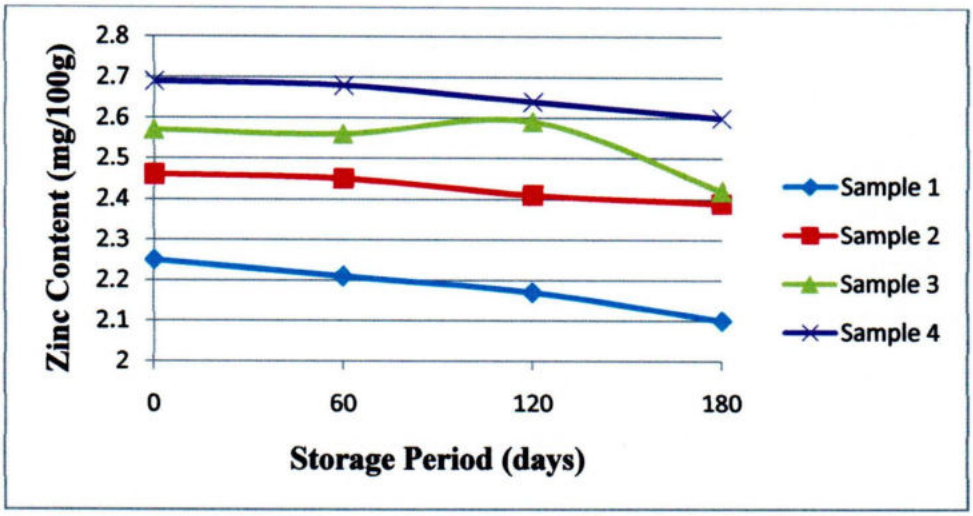


**Fig. 4.25 Pretreatment effect on the zinc content of banana powder during storage**

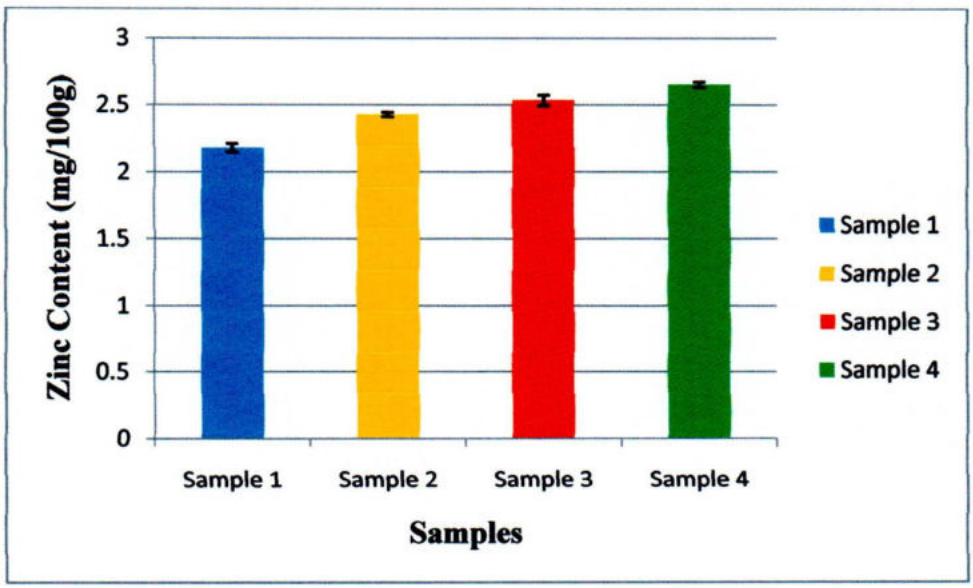


**Fig 4.26 Zinc content of banana powder based on mean score**

### 4.3.2.10 Iron content of banana powder

The mean iron content of each sample from zero (0) to 180 days at each period finally ranged between 10.17- 10.66mg/100g dry sample (Appendix 34). All the values are higher than Abbas *et al.*, (2009). The change in iron content of banana powder is shown in figure 4.27.

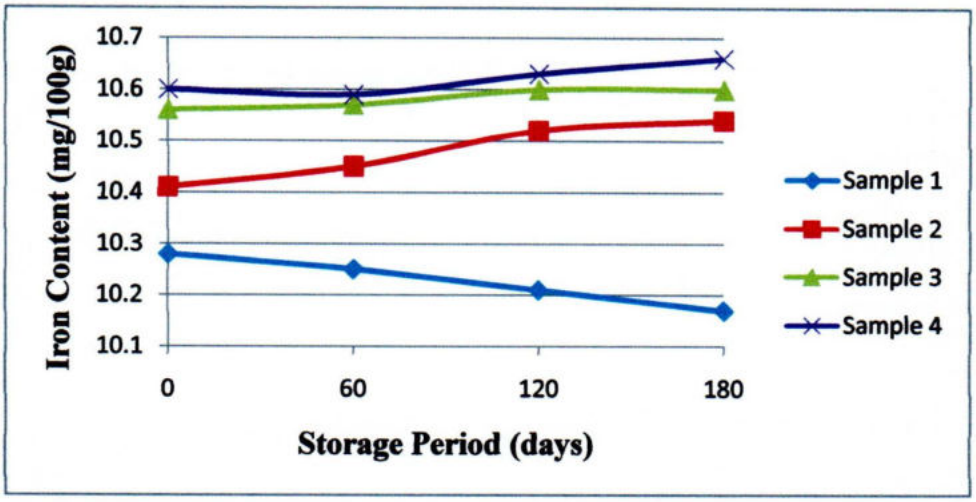


**Fig. 4.27 Pretreatment effect on the iron content of banana powder during storage**

A one way analysis of variance (ANOVA) (Appendix 35) was carried out for iron content of samples and results revealed that there were significant ($p<0.05$) differences in iron content among the samples. This indicates that the iron content of different samples of banana powder was not equally acceptable. As shown in appendix 36 (DMRT) the sample 4 secured the highest value for iron content than other samples and sample 1 has the lowest value. The mean values from appendix 36 (DMRT) are shown in figure 4.28. From the figure 4.28 we can conclude that sample 4 has the highest iron content, also change in iron content of the samples (Appendix 34; decrease of sample 1 and increase of others) 1, 2, 3 and 4 from zero (0) to 180 days are 0.11mg/100g, 0.13mg/100g, 0.04mg/100g and 0.06mg/100g dry sample respectively. Here the change in iron content of sample 3 is lowest but finally the iron content of sample 4 is highest. Therefore sample 4 is more acceptable compared to other samples.

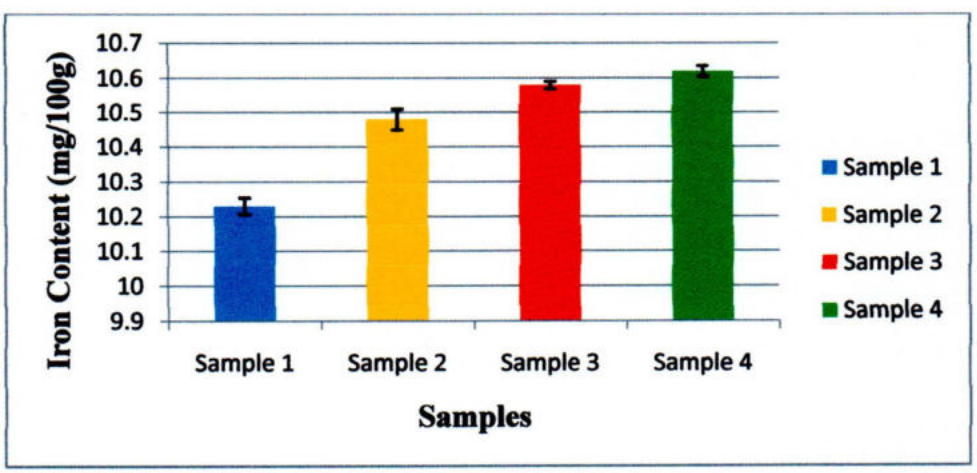


**Fig 4.28 Iron content of banana powder based on mean score**

#### 4.3.2.11 Phosphorus content of banana powder

The mean phosphorus content of each sample from zero (0) to 180 days at each period finally ranged between 77.51- 78.37mg/100g dry sample (Appendix 37). The change in phosphorus content of banana powder is shown in figure 4.29.

A one way analysis of variance (ANOVA) (Appendix 38) was carried out for phosphorus content of samples and results revealed that there were significant ($p<0.05$) differences in phosphorus content among the samples. This indicates that the phosphorus content of different samples of banana powder was not equally acceptable. As shown in appendix 39 (DMRT) the sample 4 secured the highest value for phosphorus content than other samples and sample 1 has the lowest value. The mean values from appendix 39 (DMRT) are shown in figure 4.30. From the figure 4.30 we can conclude that sample 4 has the highest phosphorus content, also change in phosphorus content of the samples (Appendix 37; decrease of sample 1 and increase of others) 1, 2, 3 and 4 from zero (0) to 180 days are 0.50mg/100g, 0.76mg/100g, 0.09mg/100g and 0.24mg/100g dry sample respectively. Here the change in phosphorus content of sample 3 is lowest but finally the Phosphorus content of sample 4 is highest. Therefore sample 4 is more acceptable compared to other samples.

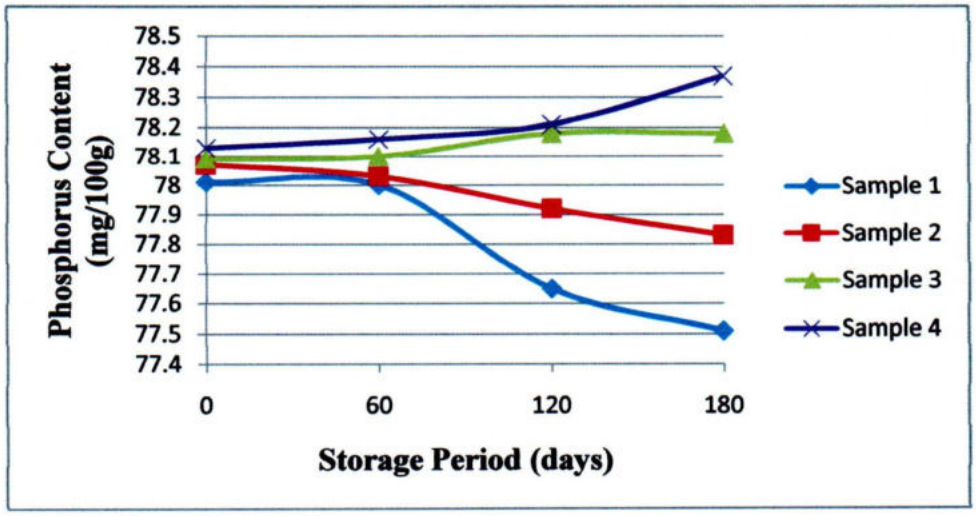


**Fig. 4.29 Pretreatment effect on the phosphorus content of banana powder during storage**

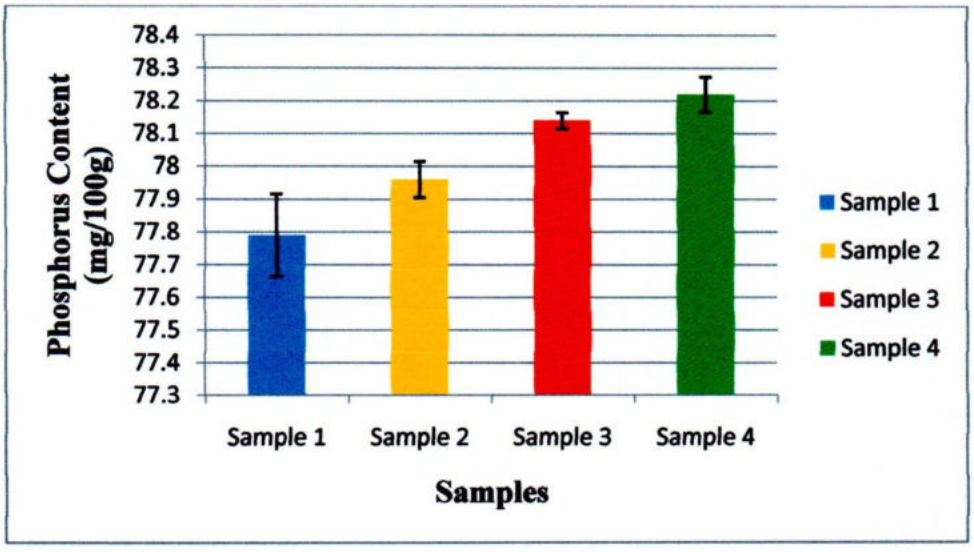


**Fig 4.30 Phosphorus content of banana powder based on mean score**

# CHAPTER V

# SUMMARY AND CONCLUSION

# CHAPTER V

# SUMMARY AND CONCLUSION

The investigation was carried out in the laboratory of the Department of Food Processing and Preservation, Hajee Mohammad Danesh Science and Technology University, Dinajpur, to prepare banana powder from ripe banana and also to determine physico-chemical properties of banana powder during storage.

The fresh ripe banana were collected from the local market and analyzed for their physical properties and chemical composition. The total carbohydrate, calcium and iron content of banana pulp are more than found in the literature.

The banana powder was prepared as per standard procedure and was analyzed for physical properties and chemical composition. The mean value of water holding capacity (WHC) of all the periods for Sample 1, 2, 3 & 4 were 2.57 g/g, 2.903 g/g, 2.783 g/g & 3.678 g/g. The oil holding capacity (OHC) of Sample 1, 2, 3 & 4 were 0.8925 g/g, 0.795 g/g, 0.8675g/g & 0.985 g/g. The moisture content of Sample 1, 2, 3 & 4 were 8.915 %, 8.113 %, 8.408 % & 6.117 %. The ash content of Sample 1, 2, 3 & 4 were 3.57 %, 2.995 %, 3.385 % & 2.548 %. The protein content of Sample 1, 2, 3 & 4 were 2.095 %, 2.287 %, 2.49% & 3.01 %. The fat content of Sample 1, 2, 3 & 4 were 0.525 %, 0.63 %, 0.6125% & 0.6625 %. The total carbohydrate content of Sample 1, 2, 3 & 4 were 84.89 %, 85.97 %, 85.1% & 87.67 %.

The mineral contents (mg/100g) were also analyzed. The potassium content of Sample 1, 2, 3 & 4 were 324.6 mg, 324.8 mg, 325.1 mg & 325.2 mg. The calcium content of Sample 1, 2, 3 & 4 were 54.85 mg, 56.62 mg, 57.15 mg & 58.31 mg. The magnesium content of Sample 1, 2, 3 & 4 were 145.7 mg, 146.7 mg, 147.3 mg & 148.4 mg. The zinc content of Sample 1, 2, 3 & 4 were 2.182 mg, 2.428 mg, 2.535 mg & 2.653 mg. The iron content of Sample 1, 2, 3 & 4 were 10.23 mg, 10.48 mg, 10.58 mg & 10.62 mg. The phosphorus content of Sample 1, 2, 3 & 4 were 77.79 mg, 77.96 mg, 78.14 mg & 78.22 mg.

Every year in Bangladesh a large amount of banana are spoiled due to inadequate processing and preservation facilities. The banana powder preparation is a simple technique for preservation. Proper utilization and value addition of banana powder

through preparation of bakery, confectionery, baby food etc. may help encourage development of small scale industries in the country.

**Conclusion**

- There is no pretreatment effect on the yield of banana powder because the yield of each sample was more or less same.
- The statistical analysis showed that Sample 4 (pretreated with mixed solution of 0.5% of citric acid & 0.1% of potassium metabisulfite) was more acceptable in most cases than Sample 1, 2 and 3.
- It indicates that higher and mixed proportions of pretreatment of banana slices before drying and grinding retained the quality and renders the nutritional change of banana powder.

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# APPENDICES

# APPENDICES

**Appendix 1 Water Holding Capacity (WHC) of Banana Powder (g/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 2.87 | 3.16 | 3.09 | 3.79 |
| 60 | 2.63 | 3.03 | 2.87 | 3.69 |
| 120 | 2.51 | 2.88 | 2.75 | 3.64 |
| 180 | 2.27 | 2.54 | 2.42 | 3.59 |

**Appendix 2 Analysis of Variance (ANOVA) for Water Holding Capacity (WHC)**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 2.798 | 0.933 | 100.5912 | 3.862548 |
| Period | 3 | 0.575 | 0.192 | 20.6612 | 3.862548 |
| Error | 9 | 0.083 | 0.009 | | |
| Total | 15 | 3.457 | | | |

**Appendix 3 Duncan's Multiple Range Test (DMRT) for Water Holding Capacity**

**LSD value = 0.1518, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $2.570^{c}$ | Sample 4 | $3.678^{a}$ |
| Sample 2 | $2.903^{b}$ | Sample 2 | $2.903^{b}$ |
| Sample 3 | $2.783^{b}$ | Sample 3 | $2.783^{b}$ |
| Sample 4 | $3.678^{a}$ | Sample 1 | $2.570^{c}$ |

**Appendix 4 Oil Holding Capacity (OHC) of Banana Powder (g/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 1.03 | 0.95 | 0.98 | 1.08 |
| 60 | 0.93 | 0.91 | 0.86 | 1.02 |
| 120 | 0.89 | 0.80 | 0.84 | 0.95 |
| 180 | 0.72 | 0.52 | 0.79 | 0.89 |

**Appendix 5 Analysis of Variance (ANOVA) for Oil Holding Capacity (OHC)**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 0.074 | 0.025 | 6.2673 | 3.862548 |
| Period | 3 | 0.168 | 0.056 | 14.2235 | 3.862548 |
| Error | 9 | 0.035 | 0.004 | | |
| Total | 15 | 0.277 | | | |

**Appendix 6 Duncan's Multiple Range Test (DMRT) for Oil Holding Capacity**

**LSD value = 0.1012, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $0.8925^{ab}$ | Sample 4 | $0.9850^{a}$ |
| Sample 2 | $0.7950^{b}$ | Sample 1 | $0.8925^{ab}$ |
| Sample 3 | $0.8675^{b}$ | Sample 3 | $0.8675^{b}$ |
| Sample 4 | $0.9850^{a}$ | Sample 2 | $0.7950^{b}$ |

**Appendix 7 Moisture Content of Banana Powder (g/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 6.07 | 5.71 | 5.12 | 4.29 |
| 60 | 8.50 | 7.70 | 8.40 | 5.35 |
| 120 | 9.57 | 8.71 | 9.22 | 6.93 |
| 180 | 11.52 | 10.33 | 10.89 | 7.90 |

**Appendix 8 Analysis of Variance (ANOVA) for Moisture Content**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 18.039 | 6.013 | 28.6071 | 3.862548 |
| Period | 3 | 50.203 | 16.734 | 79.6155 | 3.862548 |
| Error | 9 | 1.892 | 0.210 | | |
| Total | 15 | 70.133 | | | |

**Appendix 9 Duncan's Multiple Range Test (DMRT) for Moisture Content**

**LSD value = 0.7330, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $8.915^{a}$ | Sample 1 | $8.915^{a}$ |
| Sample 2 | $8.113^{b}$ | Sample 3 | $8.408^{ab}$ |
| Sample 3 | $8.408^{ab}$ | Sample 2 | $8.113^{b}$ |
| Sample 4 | $6.117^{c}$ | Sample 4 | $6.117^{c}$ |

**Appendix 10 Ash Content of Banana Powder (g/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 3.18 | 2.49 | 2.86 | 2.34 |
| 60 | 3.34 | 2.73 | 2.98 | 2.46 |
| 120 | 3.66 | 3.06 | 3.57 | 2.67 |
| 180 | 4.10 | 3.70 | 4.13 | 2.72 |

**Appendix 11 Analysis of Variance (ANOVA) for Ash Content**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 2.464 | 0.821 | 22.5992 | 3.862548 |
| Period | 3 | 2.118 | 0.706 | 19.4228 | 3.862548 |
| Error | 9 | 0.327 | 0.036 | | |
| Total | 15 | 4.909 | | | |

**Appendix 12 Duncan's Multiple Range Test (DMRT) for Ash Content**

**LSD value = 0.3035, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $3.570^{a}$ | Sample 1 | $3.570^{a}$ |
| Sample 2 | $2.995^{b}$ | Sample 3 | $3.385^{a}$ |
| Sample 3 | $3.385^{a}$ | Sample 2 | $2.995^{b}$ |
| Sample 4 | $2.548^{c}$ | Sample 4 | $2.548^{c}$ |

**Appendix 13 Protein Content of Banana Powder (g/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 2.68 | 2.73 | 3.08 | 3.20 |
| 60 | 2.37 | 2.65 | 2.83 | 3.09 |
| 120 | 2.01 | 2.21 | 2.32 | 2.91 |
| 180 | 1.32 | 1.56 | 1.73 | 2.84 |

**Appendix 14 Analysis of Variance (ANOVA) for Protein Content**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 1.864 | 0.621 | 13.3950 | 3.862548 |
| Period | 3 | 2.622 | 0.874 | 18.8476 | 3.862548 |
| Error | 9 | 0.417 | 0.046 | | |
| Total | 15 | 4.903 | | | |

**Appendix 15 Duncan's Multiple Range Test (DMRT) for Protein Content**

**LSD value = 0.3431, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $2.095^{c}$ | Sample 4 | $3.010^{a}$ |
| Sample 2 | $2.287^{bc}$ | Sample 3 | $2.490^{b}$ |
| Sample 3 | $2.490^{b}$ | Sample 2 | $2.287^{bc}$ |
| Sample 4 | $3.010^{a}$ | Sample 1 | $2.095^{c}$ |

**Appendix 16 Fat Content of Banana Powder (g/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 0.73 | 0.69 | 0.75 | 0.77 |
| 60 | 0.63 | 0.63 | 0.71 | 0.66 |
| 120 | 0.44 | 0.61 | 0.57 | 0.63 |
| 180 | 0.30 | 0.59 | 0.42 | 0.59 |

**Appendix 17 Analysis of Variance (ANOVA) for Fat Content**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 0.041 | 0.014 | 2.5745 | 3.862548 |
| Period | 3 | 0.153 | 0.051 | 9.5248 | 3.862548 |
| Error | 9 | 0.048 | 0.005 | | |
| Total | 15 | 0.243 | | | |

**Appendix 18 Duncan's Multiple Range Test (DMRT) for Fat Content**

**LSD value = 0.1131, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $0.5250^{b}$ | Sample 4 | $0.6625^{a}$ |
| Sample 2 | $0.6300^{ab}$ | Sample 2 | $0.6300^{ab}$ |
| Sample 3 | $0.6125^{ab}$ | Sample 3 | $0.6125^{ab}$ |
| Sample 4 | $0.6625^{a}$ | Sample 1 | $0.5250^{b}$ |

**Appendix 19 Total Carbohydrate Content for Banana Powder (g/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 87.32 | 88.38 | 88.17 | 89.44 |
| 60 | 85.16 | 86.29 | 85.08 | 88.44 |
| 120 | 84.32 | 85.41 | 84.32 | 86.86 |
| 180 | 82.76 | 83.82 | 82.83 | 85.95 |

**Appendix 20 Analysis of Variance (ANOVA) for Total Carbohydrate Content**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 19.229 | 6.410 | 41.4795 | 3.862548 |
| Period | 3 | 42.822 | 14.274 | 92.3757 | 3.862548 |
| Error | 9 | 1.391 | 0.155 | | |
| Total | 15 | 63.441 | | | |

**Appendix 21 Duncan's Multiple Range Test (DMRT) for Total Carbohydrate Content**

**LSD value = 0.6298, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $84.89^{c}$ | Sample 4 | $87.67^{a}$ |
| Sample 2 | $85.97^{b}$ | Sample 2 | $85.97^{b}$ |
| Sample 3 | $85.10^{c}$ | Sample 3 | $85.10^{c}$ |
| Sample 4 | $87.67^{a}$ | Sample 1 | $84.89^{c}$ |

**Appendix 22 Potassium Content of Banana Powder (mg/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 325.00 | 325.00 | 325.00 | 325.00 |
| 60 | 324.76 | 324.82 | 325.01 | 325.07 |
| 120 | 324.43 | 324.74 | 325.13 | 325.19 |
| 180 | 324.27 | 324.68 | 325.21 | 325.38 |

**Appendix 23 Analysis of Variance (ANOVA) for Potassium Content**

| **Source** | **Degree of freedom** | **Sum of squares** | **Mean squares** | **F- value** | |
|---|---|---|---|---|---|
| | | | | **Calculated** | **Tabulated** |
| Sample | 3 | 0.765 | 0.255 | 5.0426 | 3.862548 |
| Period | 3 | 0.039 | 0.013 | 0.2590 | 3.862548 |
| Error | 9 | 0.455 | 0.051 | | |
| Total | 15 | 1.259 | | | |

**Appendix 24 Duncan's Multiple Range Test (DMRT) for Potassium Content**

**LSD value = 0.3612, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $324.6^{b}$ | Sample 4 | $325.2^{a}$ |
| Sample 2 | $324.8^{ab}$ | Sample 3 | $325.1^{a}$ |
| Sample 3 | $325.1^{a}$ | Sample 2 | $324.8^{ab}$ |
| Sample 4 | $325.2^{a}$ | Sample 1 | $324.6^{b}$ |

**Appendix 25 Calcium Content of Banana Powder (mg/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 55.00 | 56.39 | 57.22 | 58.23 |
| 60 | 54.91 | 56.46 | 57.19 | 58.27 |
| 120 | 54.81 | 56.75 | 57.12 | 58.34 |
| 180 | 54.69 | 56.88 | 57.09 | 58.41 |

**Appendix 26 Analysis of Variance (ANOVA) for Calcium Content**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 24.888 | 8.296 | 318.1201 | 3.862548 |
| Period | 3 | 0.011 | 0.004 | 0.1451 | 3.862548 |
| Error | 9 | 0.235 | 0.026 | | |
| Total | 15 | 25.134 | | | |

**Appendix 27 Duncan's Multiple Range Test (DMRT) for Calcium Content**

**LSD value = 0.2579, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $54.85^{d}$ | Sample 4 | $58.31^{a}$ |
| Sample 2 | $56.62^{c}$ | Sample 3 | $57.15^{b}$ |
| Sample 3 | $57.15^{b}$ | Sample 2 | $56.62^{c}$ |
| Sample 4 | $58.31^{a}$ | Sample 1 | $54.85^{d}$ |

**Appendix 28 Magnesium Content of Banana Powder (mg/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 145.70 | 146.56 | 147.20 | 148.5 |
| 60 | 145.70 | 146.62 | 147.29 | 148.52 |
| 120 | 145.70 | 146.77 | 147.31 | 148.00 |
| 180 | 145.70 | 146.86 | 147.43 | 148.44 |

**Appendix 29 Analysis of Variance (ANOVA) for Magnesium Content**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 14.940 | 4.980 | 216.3806 | 3.862548 |
| Period | 3 | 0.057 | 0.019 | 0.8303 | 3.862548 |
| Error | 9 | 0.207 | 0.023 | | |
| Total | 15 | 15.204 | | | |

**Appendix 30 Duncan's Multiple Range Test (DMRT) for Magnesium Content**

**LSD value = 0.2426, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $145.7^{d}$ | Sample 4 | $148.4^{a}$ |
| Sample 2 | $146.7^{c}$ | Sample 3 | $147.3^{b}$ |
| Sample 3 | $147.3^{b}$ | Sample 2 | $146.7^{c}$ |
| Sample 4 | $148.4^{a}$ | Sample 1 | $145.7^{d}$ |

**Appendix 31 Zinc Content of Banana Powder (mg/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 2.25 | 2.46 | 2.57 | 2.69 |
| 60 | 2.21 | 2.45 | 2.56 | 2.68 |
| 120 | 2.17 | 2.41 | 2.59 | 2.64 |
| 180 | 2.10 | 2.39 | 2.42 | 2.60 |

**Appendix 32 Analysis of Variance (ANOVA) for Zinc Content**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 0.481 | 0.160 | 181.4309 | 3.862548 |
| Period | 3 | 0.031 | 0.010 | 11.6018 | 3.862548 |
| Error | 9 | 0.008 | 0.001 | | |
| Total | 15 | 0.520 | | | |

**Appendix 33 Duncan's Multiple Range Test (DMRT) for Zinc Content**

**LSD value = 0.05058, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $2.182^{d}$ | Sample 4 | $2.653^{a}$ |
| Sample 2 | $2.428^{c}$ | Sample 3 | $2.535^{b}$ |
| Sample 3 | $2.535^{b}$ | Sample 1 | $2.428^{c}$ |
| Sample 4 | $2.653^{a}$ | Sample 2 | $2.182^{d}$ |

**Appendix 34 Iron Content of Banana Powder (mg/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 10.28 | 10.41 | 10.56 | 10.60 |
| 60 | 10.25 | 10.45 | 10.57 | 10.59 |
| 120 | 10.21 | 10.52 | 10.60 | 10.63 |
| 180 | 10.17 | 10.54 | 10.60 | 10.66 |

**Appendix 35 Analysis of Variance (ANOVA) for Iron Content**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 0.375 | 0.125 | 58.9556 | 3.862548 |
| Period | 3 | 0.003 | 0.001 | 0.4791 | 3.862548 |
| Error | 9 | 0.019 | 0.002 | | |
| Total | 15 | 0.398 | | | |

**Appendix 36 Duncan's Multiple Range Test (DMRT) for Iron Content**

**LSD value = 0.07154, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $10.23^{c}$ | Sample 4 | $10.62^{a}$ |
| Sample 2 | $10.48^{b}$ | Sample 3 | $10.58^{a}$ |
| Sample 3 | $10.58^{a}$ | Sample 2 | $10.48^{b}$ |
| Sample 4 | $10.62^{a}$ | Sample 1 | $10.23^{c}$ |

**Appendix 37 Phosphorus Content of Banana Powder (mg/100g)**

| Days | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|
| 0 | 78.01 | 78.07 | 78.09 | 78.13 |
| 60 | 78.00 | 78.03 | 78.10 | 78.16 |
| 120 | 77.65 | 77.92 | 78.18 | 78.21 |
| 180 | 77.51 | 77.83 | 78.18 | 78.37 |

**Appendix 38 Analysis of Variance (ANOVA) for Phosphorus Content**

| Source | Degree of freedom | Sum of squares | Mean squares | F- value | |
|---|---|---|---|---|---|
| | | | | Calculated | Tabulated |
| Sample | 3 | 0.431 | 0.144 | 5.5525 | 3.862548 |
| Period | 3 | 0.035 | 0.012 | 0.4494 | 3.862548 |
| Error | 9 | 0.233 | 0.026 | | |
| Total | 15 | 0.698 | | | |

**Appendix 39 Duncan's Multiple Range Test (DMRT) for Phosphorus Content**

**LSD value = 0.2579, P<0.05**

| Sample Code | Original order of means | Sample Code | Ranked order of means |
|---|---|---|---|
| Sample 1 | $77.79^{b}$ | Sample 4 | $78.22^{a}$ |
| Sample 2 | $77.96^{ab}$ | Sample 3 | $78.14^{a}$ |
| Sample 3 | $78.14^{a}$ | Sample 2 | $77.96^{ab}$ |
| Sample 4 | $78.22^{a}$ | Sample 1 | $77.79^{b}$ |