

**ADDIS ABABA UNIVERSITY**  
**SCHOOL OF GRADUATE STUDIES**  
**FACULTY OF TECHNOLOGY**  
**DEPARTMENT OF CHEMICAL ENGINEERING**



**PRODUCTION AND QUALITY EVALUATION OF SPRAY  
DRIED FRUIT PRODUCTS**

**A Thesis Submitted to the School of Graduate Studies of Addis Ababa  
University in Partial Fulfillment of the Requirements for the Degree of  
Masters of Science in Chemical Engineering  
(Food Engineering)**

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**Addis Ababa University**

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## **List of Abbreviations**

SME	-----	Small- and Medium-sized Enterprise
MOARD	-----	Ministry of Agriculture and Rural Development
UAAIE	-----	Upper Awash Agro-Industry Enterprise
HDE	-----	Horticulture Development Enterprise
FAO	-----	Food and Agriculture Organization
EHNRI	-----	Ethiopian Health and Nutrition Research Institute
AOAC	-----	Association of Official Analytical Chemists
CSA	-----	Central Statistical Authority
SD	-----	Standard Deviation
SNNPR	-----	Southern Nations, Nationalities and Peoples' Region
SME	-----	Small and Medium Size Enterprise
CFC	-----	Common Fund for Commodities
EPHEA	-----	Ethiopian Horticulture Exporters Association,
USAID	-----	United States Agency for International Development

## **Abstract**

*Fruits and fruit products are the enigma of food in modern society. Fresh fruits are perishable and have limited shelf life. To prolong shelf life, various processing and preservation methods such as drying, chemical treatments and various packaging methods are used. Spray drying of mango and banana pulp into powder is a challenging operation, mainly due to heat sensitive and hygroscopic nature of the fruits. Identification of the optimum inlet temperature and flow rate is crucial for proper drying to produce powders using spray driers. This study was conducted using a laboratory scale mini spray dryer to develop mango and banana powders and evaluate their sensory qualities. The improved mango (Tommy) variety was obtained from Upper Awash Agro-industry Enterprise and the local Arbaminch mango and banana were purchased from the local market in Addis Ababa. The experiments on spray drying and product quality analysis were carried out in the Food Engineering laboratory of the Department of Chemical Engineering, Addis Ababa University. Laboratory analysis of the proximate composition was conducted at the Ethiopian Health and Nutrition Research Institute (EHNRI). The development of mango and banana powders involved: cleaning, peeling, stone removal, chopping, pulping, dilution, filtration and spray drying. Feed flow rate and inlet temperature were varied at 3.6 and 4.5 ml/min (12 and 15 % of pump rate) and 200,210°C for mango powder and 3.6 and 4.5 ml/min(12 and 15 % of pump rate) and 170,180°C for banana powder, respectively. Physico-chemical properties of the fruits were determined. The mango and banana powders were analyzed for bulk density, particle size, residual moisture content, soluble solids, protein content, fat content, crude fiber content and, vitamin C. Sensory evaluation was conducted for both mango and banana powders. The collected data were subjected to analysis of variance using statistical software SPSS version 17. The inlet temperature and flow rate were found to have significant effect ( $P < 0.05$ ) on the yield, moisture, solubility and bulk density of mango and banana powders. As inlet temperature increased from 200<sup>0</sup> C to 210<sup>0</sup> C for mango pulp and from 170<sup>0</sup> C to 180<sup>0</sup> C for banana pulp and flow rate from 3.6 and 4.5 ml/min(12 and 15 % of pump rate) , the mango and banana powder yield decreased 24.5 g to 20 g and from 12.5g to 10.35g ,respectively. Sensory evaluation results showed that 75% of the panelists preferred the mango powder produced at inlet temperature of 200<sup>0</sup>C and 3.6 ml/min flow rate(12% of pump rate), while*

*62.5% of them preferred the banana powder manufactured at 170 °C and 3.6 ml/min flow rate(12% of pump rate). Processing*

*of mango and banana fruits using spray dryer is capable of producing powder that retains nutritional values, colour, and aroma and is suitable for commercialization. This study clearly indicated that especially there is an opportunity for mango powder production in the country. Based on the findings, an economically feasible processing technology for mango powder production has been suggested.*

*Key words: Banana; Mango Powder; Quality; Sensory Evaluation; Spray drying*

# **CHAPTER ONE**

## **INTRODUCTION**

### 1.1 Background

The manufacturing industrial sector is the most dynamic component of the goods producing sectors of all economy. Expansion and development of the manufacturing sector increases agricultural productivity through providing agricultural inputs and creating demand for agricultural outputs. In particular, Small- and medium-sized enterprises (SMEs) play a very important role in the overall economic growth of developing countries. In many of developing countries, smaller enterprises account for a large share of total employment. They provide a productive outlet for the entrepreneurial spirit of individuals and assist in the dispersion of business activity throughout the economy. They are a key component in economic life, not only because of their number and variety, but because of their involvement in every aspect of the economy; their contribution to regional development; the complementary role they play in support of the large sector; and their role as a proving ground for innovations and adaptations (ITC, 1993).

Ethiopia's wide range of agro-climatic conditions and soil types make it suitable for the production of diverse varieties of fruits and vegetables, including temperate, tropical and sub-tropical crops. Most of the soil types in fruits and vegetables producing regions of the country range from light clay to loam and are well suited for horticultural production. The source of varieties of fruits and vegetables in Ethiopia can be categorized into two major groups: exotic and endemic ones. State farms and newly emerged private commercial farms usually use exotic varieties, while the small farm holders are mainly confined to local or traditional varieties. Horticultural production offers the best possible undertaking among the existing agricultural enterprises due to the special characteristics of most horticultural crops. They are of relatively high value adding which makes them suitable where land area is limited and labor intensive. Therefore, they would go long way in solving the existing unemployment problems. They are also suitable to small-scale farming which is predominant in Ethiopia. Fruit crops have significant importance with a potential for domestic and export markets and industrial processing. Pineapples, passion fruits, bananas, avocados, citrus fruits,

mangoes, mandarin, papayas, guava, grapes, asparagus and vegetable crops of economic importance such as tomato, melon, pepper, chilies, onion, carrot, green beans, green peas, cabbages, okra, cauliflower, and cucumbers are produced in Ethiopia. The major vegetables produced for domestic consumption are cabbages, tomatoes and onion, while green beans and peas have recently emerged for export market. The total area under fruits, vegetables and root crops is about 356 thousand hectare in 2008/09 (CSA, 2006).

Less than 10 % of the total production is held by large state farms, while small holders account for some 92% of the acreage and 90% of the yield (Dendana et al., 2005). Some of the constraints of horticultural production are related to the perishable nature of their product. This is a major problem especially when marketing horticultural product. During peak harvest seasons, fruit and vegetables are sold at throw away price because of lack of means to preserve and store the products. Therefore, in order to prolong the shelf life of the post harvested product, processing is necessary. Processing contributes towards expansion of market of the processed products in availing it during off-seasons and also increasing its value. Producers of fruit and vegetables will increase production if there is a market for their produce. In Ethiopia, fruits and vegetables processing sector is underutilized. Currently, there are only 5 fruits and vegetables processing plants in the country.

Table1.1 describes the location, major products and production capacity of the current fruits and vegetables processing plants in Ethiopia. These plants presently process limited products: tomato paste, orange marmalade, guava nectar, vegetable soup, canned vegetables and wine. In general, processed products are mainly geared to domestic markets.

Table1.1. Capacity of fruits and vegetables processing plants in Ethiopia.

Name of processing plant	Location	Ownership	Major products	Production capacity
Melge Wendo food processing factory	Melge Wendo	Private	Tomato paste Peeled tomato	30 ton/day
Gonder Food processing factory	Gonder	Private	Tomato paste	1,250 can in a single shift
Merti Processing factory	Merti/oromia	State owned	Tomato paste Orange marmalade	5000 tons/year
Awash Winery	Addis Ababa	State owned	Wine	10.9million liters/year
Green Star Food Company	Debrezeit	Private	Canned vegetable	9,990tons/year

Source: Elias (2007)

The factory's processing capacity could reach only 41,000 quintals if tomato products are processed throughout the year. On the other hand, it could process over 61,000 quintals per year if only orange products are processed throughout the year. When the two products are mixed in equal amounts over a production cycle of one year, the factory's processing capacity will be lowered to 40,000-41,000 quintals per year (Elias, 2007).

The horticultural sector in Ethiopia is growing strongly. Major part of this growth is created by investments in the horticultural sector. Recently more and more interest from the Dutch private sector is shown in the Ethiopian fruits and vegetable sector. Farmers are also expanding their fruit and vegetable production. Local investor who is interested to invest in area of fruit and vegetable production are increasing (Elias, 2007).

The Ethiopian government, sector organizations (EPHEA) and donors (USAID, SNV, CFC) have identified potentials for the further development of fruits and vegetable sector in Ethiopia both for the domestic and export market. Also in the Ethiopian Netherlands Horticultural Partnership Programme, technical support to the development of the fruits and vegetable sector has been prioritized. A number of actors and donors have already started activities in the area of technical production assistance, post harvest handling and compliance to international standards. The number of small scale producers involved in horticulture is estimated at 5.7 million farmers. Few smallholder farmers are engaged in out grower's arrangements and some farmer's association unions have been established.

Total fruit production is almost 500 thousand tones, of which the State Farms account for approximately 10% of production. The main fruits produced and exported are bananas, citrus, grapefruit, mangoes, papaya and avocados. The main export markets for these Ethiopian fruits are Djibouti, Saudi Arabia, Yemen and Sudan. The majority of citrus production is still largely confined to state farms, but the productivity of their orchards is on the decline. Upper Awash has a plantation of mangos, mainly for export and produces mango seedlings for sale. The company Green Focus allocated 270ha for mango production in Wollega and planned to cultivate 2,000ha more of it in the coming three years and planned to build an agro processing plant (Wiersinga, 2009).

Growing and marketing of fresh produce in Ethiopia are complicated by post harvest losses both in terms of quantity and quality between harvest and consumption. The quality of fresh fruits depends on the post harvest handling during harvesting, transportation, and storage (Haidar & Demisse, 1999). Compared with several temperate fruits, the tropical and subtropical fruit such as mango, banana and papaya presents greater problems in storage and transportation because of their perishable nature ( Baldwin, 1997). The post harvest losses of perishable commodities is estimated to be as high as 50% in Ethiopia (FAO, 1981). The production, marketing and consumption of mango, banana and papaya fruits are restricted due to improper handling, inadequate transport and storage facility, disease problems, and sensitivity to low storage temperature (Baldwin, 1997). Even though Ethiopia is experiencing huge post harvest losses, very little emphasis has been laid on the post harvest handling (Tadesse, 1991).

Dried food powders are used in nutritional supplements, prepared meals, powdered drinks, breakfast cereals, dessert mixes, soup mixes, and other food and nutritional products. Dehydration of liquids allows for long-term storage of fruit and vegetable powders thus allowing preservation of vitamins and other nutrients in fresh fruits and vegetables that are critical for human health. Extensive research on antioxidants and their importance in preventing cancer, heart disease, and aging is providing impetus for food processors to enhance the preservation of the quality of fresh foods (Cadenas, 2002). Of developed countries, including the United States, between 11- 20% of total industrial energy consumption is from drying operations (Mujumdar,2001and Baker, 2005). With increasing demand for food preservation and dehydrated food products this number is expected to increase throughout the world due to population growth and increasing transportation costs. Radiant Zone Drying provides a low cost alternative to producing high quality food powders. Fresh food and discarded agricultural waste streams can be processed into value added nutritional ingredients and dehydrated for long-term food storage. Liquid drying methods with a rapid drying rate, low powder manufacture costs, low energy consumption, and capable of preserving initial fresh food quality by limiting additives and preventing oxidative and thermal degradation is paramount in food processing (Vega-Mercado etal ,2001).

Fruits and fruit products are the enigma of food in modern society. Fresh fruits are perishable and have limited shelf life. To prolong shelf life, various processing and preservation methods such as drying, chemical treatments and various packaging methods are used. Drying is the major food processing operation to increase the shelf life.

The purpose of drying of fruit and vegetable juices is to produce a stable and easily handled form of the juice, which reconstitutes rapidly to a quality product resembling the original juice as closely as possible. A dried juice product, today, are used mainly as convenience foods and has long storage life at ordinary temperatures. Completely dried fruit powders are often used for making many delicious food products. Fruit powders less than 4% (wb) moisture content can be used to make candy, toffee, fudge and hard candy (Mani, 2002).

There are several drying techniques for production of food powders. They are: hot air, vacuum, freeze and spray drying. Among them spray drying is the simplest and commercially used method for transforming a wide variety of liquid food products into powder form. Spray dryer uses hot air and can use fairly high air temperatures because the drying temperature drops drastically as water evaporates from the product being dried. The drying process can be completed within a short period of time, thus enabling to prepare dried fruit powder without heat degradation even at comparatively high air temperatures

## **1.2. Statement of the Problem**

Ethiopia's wide range of agro-climatic conditions and soil types make it suitable for the production of fruits . Unlike durable crops such as cereals, pulses and oilseeds, fresh fruits are highly perishable, and must be either marketed or processed immediately after harvesting. Fruits generate large quantities of valuable waste that ends up as garbage. However, if they are gainfully utilized at the proper time they can become value added products.

Horticultural production offers the best possible undertaking among existing agricultural enterprises due to their significant important with a potential for domestic consumption, export market, and industrial processing. But, there are major problems limiting the expansion of fruits processing industries: shortage of raw materials, lack of knowledge and experience. Some of constraints of post harvest products of fruits are related to the perishable nature of the fruit and their condition and market life are highly affected by such things, as temperature, humidity and the composition of the atmosphere. Growing and marketing of fresh produce in Ethiopia are complicated by post harvest losses both in terms of quantity and quality between harvest and consumption. Fresh fruits are perishable and have limited shelf life. To prolong shelf life, various processing and preservation methods such as drying, chemical treatments and various packaging methods are used. Drying is the major food processing operation to increase the shelf life. The purpose of drying of fruit juices is to produce a stable and easily handled form of the juice, which reconstitutes rapidly to a quality product resembling the original juice as closely as possible. Dried juice products today are used mainly as convenience foods and have long storage life at ordinary temperatures. Completely dried fruit powders are often used for making many delicious food products.

In Ethiopia, the number of fruits and vegetables processing industries is limited. Currently, there are only 5 fruits processing plants in the country. These plants presently process a limited variety of products: tomato paste, orange marmalade, vegetable soup, frozen vegetables and wine. Currently most processed products are geared to domestic markets.

During peak harvesting seasons, the loss is high and the fruits are sold at low price because of lack of means to preserve and store the products. Besides, the country is not getting foreign currency from horticultural crops due to the low levels of post harvest technology, which makes the product inferior quality and has no chance of competing in the world market. Therefore, in order to prolong the shelf life of the post harvest product, processing is necessary. Processing contributes toward expansion of market of the processed products in availing it during off-seasons and also increasing its value.

### **1.3. Objectives**

The general objective was to develop a spray dried fruit powder (mango powder, and banana powder), and evaluate the quality of the products.

#### **Specific objectives were :**

- ☞ To produce spray dried fruit powders with consumer acceptance
- ☞ To study their physicochemical properties and sensory quality; and
- ☞ To suggest a small scale fruit powder production technology

# **CHAPTER TWO**

## **LITERATURE REVIEW**

### **2.1 History of Food Processing**

Food processing dates back to the prehistoric age when crude processing including various types of cooking, such as over fire, smoking, steaming, fermenting, sun drying and preserving with salt were in practice. Foods preserved this way were a common part of warriors' and sailors' diets. These crude processing techniques remained essentially the same until the advent of the industrial revolution. Nicolas Appert developed a vacuum bottling process to supply food to troops in the French army, which eventually led to canning in tins by Peter Durand in 1810. Modern food processing technologies, in the 19th century were also largely developed to serve military needs. In the early 20th century, the space race, change in food habits and the quality consciousness of the consumers in the developed world furthered the development of food processing with advancements such as spray drying, juice concentrates, freeze drying and the introduction of artificial sweeteners, colourants, and preservatives. In the late 20th century products including dried instant soups, reconstituted fruit juices, and self cooking meals such as ready-to-eat food rations etc., were developed (Shruti , 2007)

### **2.2 Importance, Scope and Benefits of Processing of Horticultural Crops**

Horticulture is a crucial component of agriculture, which is the mainstay of Ethiopian economy. Horticulture sector includes fruits, vegetables, root and tuber crops, spices, mushrooms, honey, floriculture, medicinal and aromatic plants and nuts. In spite of having varied agro-climatic conditions, abundance of natural resources like sunlight and water, sufficient labour availability and abundant produce, our country is trailing behind in productivity, export and processing of horticultural produce as compared with other horticultural advanced countries. Further, due to lack of adequate post harvest handling, processing and infrastructure facilities, post harvest losses caused by spoilage are very high ( Tefera *et al.*,2006 )

**The benefits of food processing are that it:**

- Converts raw food and other farm produce into edible, usable and palatable form.
- Helps to store perishable and semi-perishable agricultural commodities, avoid glut in the market, check post harvest losses and make the produce available during off-season.
- Generates employment
- Development of ready-to-consumer products hence saves time for cooking
- Helps in preservation
- Helps in improving palatability and organoleptic quality of the produce by value addition
- Helps in easing marketing and distribution tasks
- Increases seasonal availability of many foods
- Enables transportation of delicate perishable foods across long distances Makes foods safe for consumption by checking of pathogenic microorganisms
- Food processing can also bring nutritional and food security
- Provides potential for export to fetch foreign exchange

Preserving food requires the control of enzymes and microorganisms. Microorganisms which grow rapidly on raw or fresh food products can be controlled by drying because the lack of water limits the growth of microorganisms; however, drying does not kill the microorganisms. Inactivation of enzymes in the fruit or vegetable is usually controlled by a pretreatment. Enzymes can catalyze undesirable flavor and color changes.

**2.3 Tropical Fruits**

There are a number of semi-tropical and strictly tropical fruit both with recognized and unrecognized juice, puree or pulp potential. Processing technology, including juice products from the better-known fruits such as pineapple, guava, mango, banana, papaya and passion fruit have been well covered by Nagy *et al.*, (1993).

### **2.3.1 General Overview of Fruit**

Fruit quality goes back to tree stock, growing practices and weather conditions. Closer to the shipper and processor, however, are the degrees of maturity and ripeness when picked and the method of picking or harvesting.

From a technological point of view, fruit characterization by species and varieties is performed on the basis of physical as well chemical properties: shape, size, texture, flavour, colour/pigmentation, dry matter content (soluble solids content), pectic substances, acidity, vitamins, etc. These properties are directly correlated with fruit utilization (Shruti , 2007)

Fruit or vegetables should be carefully packed into baskets, trays or crates for transporting to the processing site. The more fragile fruits need to be packed in single layers to prevent crushing those at the bottom. It is advisable to sort fruits and vegetable by size and package those of similar size together, for optimal use of space and to protect smaller produce from being damaged by larger and heavier produce. Avoid packaging too many fruits or vegetables in one container, to prevent crushing and bruising of the produce. But avoid packaging too few fruits and vegetables into containers, to prevent the produce from moving around and becoming damaged during transport (Shruti , 2007)

### **2.3.2. Ethiopian Fruit Production and Export potential**

The agricultural sector accounts for 55% to the Gross Domestic Product and provides 85% of employment. Ethiopia produces mainly variety of cereals, pulses, oilseeds, and coffee. Grains are the most important field crops. Vegetable and fruit production and consumption is very limited. Small-scale farmers, who account for 90% of output, farm an estimated 96% of total cropped land (Greenhalgh, 2005).

Number of small scale producers involved in horticulture is estimated at 5.7 million farmers (MOARD, 2007). In the fruits and vegetable sector, exports are still dominated by the two state farm operations, namely Upper Awash Agro-Industry Enterprise (UAAIE) and Horticulture Development Enterprise (HDE), both established in 1979/80 and both currently in the process of being privatized. Alongside the state companies a number of private sector companies and cooperatives are involved in relatively small-scale production, processing and export of vegetable products. The past few years have seen a major change in Government policies towards the

horticultural sector, reflecting efforts to redirect the economy away from centralized planning to a more liberalized economy. The Government increasingly considers the private sector as the engine of economic growth and the catalyst for employment creation and export expansion (Greenhalgh , 2005). As a result private companies were allowed and facilitated with an array of incentives to engage in the sector.

In developing countries agriculture is the mainstay of the economy. As such, it should be no surprise that agricultural industries and related activities can account for a considerable proportion of their output. Of the various types of that can be termed as agriculturally based, fruits processing are among the most important. The main objective of fruit processing is to supply wholesome, safe, nutritious and acceptable food to consumer throughout the year.

Fruit juices are beverages with a high nutritional content of vitamins and minerals. They are generally considered to contain antioxidants for human health. The best way to consume fruit and vegetable juice is to drink the fresh juice immediately obtained from simple squeezing. To some extent this might not be convenient in the daily life of most people. In addition, fruits are seasonal products. During the season the production is often in excess. Storage is needed in order to have the juice last longer or to last for the rest of the year. Commercially, fruit juices are generally available as two types of product, pasteurized fresh juice and juice reconstituted from concentrate (FAO, 2008).

Concentration can reduce the storage volumes and facilitates the preservation for a longer shelf life. A better preservation of fruit juice might be in a powdered form. Juice in a powdered form has packaging, storage and transportation advantages. It is convenient for instant use in liquid preparations and in various application including seasoning blends, confectionary, pharmaceuticals, beverage mixes, weaning foods and health products. The structure and functional aspects of fruits dictate their composition. Juice powder can be produced by many methods, such as vacuum, freeze, drum, air and spray drying. The techniques to dry fruit juice are very specific for each drying method. Unfortunately, the sugar and acid content of fruit juice makes the drying process very complicated. The drying complication is related to physico-chemical changes during drying of the juice. A drying aid is a necessary part of the fruit juice drying. The high sugar content, consisting primarily of the reducing sugars, glucose and fructose, and also acidity in fruit juice presents a

problem (Bhandari *et al.*, 1993). At low moisture levels the products are very hygroscopic, readily picking up moisture from the air to become sticky and difficult to handle (Kudra, 2003; Jayaraman & Gupta, 2007). Fruit juice powders must be protected from the atmosphere during and after drying (Bates *et al.*, 2001). Table 2.1 shows some typical constituents of fruit (and subsequently juices) and the range of values dependent upon fruit, cultivar, cultivation, maturity and other factors.

Table 2.1 Fruit edible portion composition ranges\* (Fresh weight basis).

Component	Range (%)	Comment
water	97-70	Influenced by cultivation and post harvest condition
Carbohydrate	25-30	Sugar and polymer-pectin, hemicelluloses, celluloses
protein	5-trace	More in oily fruit and seed
Lipid	25-trace	Traces in cell membrane, in seeds, high in avocado
Acid	3-trace	citric, Tartaric, Malic, Lactic, Acetic, Ascorbic
Phenolics	0.5-trace	Tannin and complex phenol
Vitamin	0.2-trace	Water soluble > Fat soluble
Mineral	0.2-trace	Soil and species dependence
Dietary fiber	<1 to >15	Peel and core dependent
Pigments	0.1-trace	Carotenoid, Chlorophyll

Source: USDA, 2000.

### 2.3.3 Mango

The Mango (*Mangifera indica* L.) is the most economically important fruit in the Anacardiaceae family and is known to have originated from Asia particularly from the Indo-Burmese region approximately 4000 years ago. Mango trees are favored by tropical and subtropical climates, are evergreen, grow to about 18 m and bear fruits 4–6 years after planting. Among internationally traded tropical fruits, mangoes rank second only to banana both in quantity and value and fifth in total production among major fruit crops worldwide. The world production of mangoes is estimated to be over 26 million tons per annum. India ranks first among the world's mango producing

countries, accounting for 54.2% of the total mangoes produced worldwide and it is commercially the most important fruit crop in India, with more than a thousand varieties known to date.

Other prominent mango producing countries include China, Thailand, Indonesia, Philippines, Pakistan, and Mexico. Mango cultivars can broadly be classified into two groups, Indian and Indo-Chinese, based mainly on peel pigments and sensory characteristics of the pulp. Alphonso is the leading commercial variety and rated best in the world. It is attractive to consumers because of its good quality characteristics like thin skin, soft flesh, low fiber content, sweet aroma, and an excellent sugar: acid ratio. The mango fruit is classified as an in deliquescent drupe, and contains a single large seed surrounded by a fleshy mesocarp covered by a leathery skin. Industrially, there are three parts of interest from the mango fruit namely—the pulp, peel, and the seed. Conventionally the mango pulp is the main focal point in mango utilization both domestically and industrially.

### 2.3.3.1 Nutritional Value of Mango

Mangoes are bursting with protective nutrients. The vitamin content depends upon the variety and maturity of the fruit. When the mango is green the amount of vitamin C is higher and as it ripens the amount of beta carotene (vitamin A) increases. Bautista (1996) stated that mango is a good source of vitamin A and C and this edible fruit is rich in carbohydrates, minerals potassium, and phosphorus.

Table 2.2 Food value per 100g of ripe mango pulp

No	Component	Amount
1	Calories	62.1-63.7
2	Water, g	78.9-82.8
3	Protein, g	0.36-0.40
4	Fat, g	0.30-0.53
5	Carbohydrates, g	16.20-17.18
6	Fiber, g	0.85-1.06
7	Ash, g	0.34-0.52
8	Calcium ,mg	6.1-12.8
9	Phosphorus, mg	5.5-17.9
10	Iron ,mg	0.20-0.63
11	Vitamin A(Carotene),mg	0.135-1.872
12	Thiamine , mg	0.020-0.073
13	Riboflavin ,mg	0.025-0.068
14	Niacin ,mg	0.025-0.707
15	Ascorbic Acid, mg	7.8-172.0
16	Tryptophan ,mg	3-6
17	Lysine, mg	32-37
18	Methionine ,mg	4

Source: Gopalan, *et al.*(1987)

There are thousands of varieties in the world however, only about 30 varieties are grown on commercial scale. The types of locally available varieties are not well known. But varieties like Tommy Atkins, Kent and keitt are under cultivation in the Upper Awash Agro Industry. (Hordofa and Chemed, 2005).

Table 2.3 Proximate composition (g/ kg) of processed mango kernel flour

No	Component	Amount
1	Moisture	91.00
2	Protein	66.10
3	Fat	94.00
4	Fiber	28.00
5	Ash	10.80
6	Soluble carbohydrate	27.50
7	Starch	500.0
8	Carbohydrate	182.6
9	Caloric value(kj/kg)	16.60
10	Ascorbic acid	0.17
11	Tannin(as catechin)	23.40

Source: Arogba et al.,(1999)

### 2.3.3.2 Mango processing

Mango is perhaps one of the most important fruits of the world which can be utilized by the processing industry during the different stages of its growth, development, maturity and ripening. The products prepared both from ripe and green mangoes are highly popular in India and abroad. India dominated the world trade of processed mango products, even though hardly 1% of the total mango production in India is processed.

Export of processed mango products is continuously increasing. The major export product is canned mango pulp, which has increased over the past decade by about three times in volume and five times in value. Various processed products which can be prepared from both green and ripe mangoes.

Mango is a very popular tropical fruit in the Ethiopia but is seasonal in nature. Due to this property, it is desirable to process it for future use. The result of the study on manufacturing of mango juice will inspire mango growers because it will add to the marketability of their product. Likewise, it may add income to the homemakers who would like to undertake processing. Furthermore, homemakers, researchers and extensionists will find more information for their work. The season for mangoes in

Ethiopia starts in January to April and from September to November. Mangoes are mainly produced in West and East of Oromia, SNNPR, Benshangul and Amhara. The amount of mango production and cultivation area of the country is not known (Desta , 2005.). .

The mango market is mostly domestic and the production system is suited by farmers. In the domestic market, consumption is largely in its fresh form, however, nowadays, a demand for canned mango juice is growing.

The fruit processing industry in Ethiopia is very weak, considering the substantial amount of fruit that is grown in the country. No doubt, one of the reasons for this is the highly developed processing industries in other countries which are able to export into countries like Ethiopia and sell the final product at low cost (Desta , 2005.). Indeed, there were a number of imported, long-life mango juice brands available throughout Ethiopia and is certain to act as a competitive entry barrier for domestically produced and producing juice.

Investigations of local processors found only one significant player, who actually imported frozen mango flesh from India for processing juice in Ethiopia. The main considerations for purchasing Indian imports were the variety, quality, consistency, and price of the imports.

The informant did however predict that juice processing would begin to emerge as a more viable sector, as mango juice is clearly the most favored juice product by consumers. He indicated that demand for the juice as a category was seeing strong growth, with mango leading this growth.

Table2.4. Annual production of mango fruit in Ethiopia

Production year	Amount in quintal(thousand)
2003/2004	292.283
2004/2005	301.71
2005/2006	547.29
2006/2007	626.11
2007/2008	484.36
2008/2009	441.58

Source: CSA (2009)

### 2.3.3.3 World Market for Mango Products

The mango (*Mangifera indica* L) is one of the most important tropical and subtropical fruit of the world and is popular both in the fresh and the processed form. It is commercially grown in more than 80 countries. India occupies 54% of the world's production of mango which is nearly 9.5 m. tonnes. The other leading mango producing countries of the world are China, Mexico, Pakistan, Indonesia, Thailand, Nigeria, Brazil, Philippines and Haiti. Less than 10% of total world production of mango is exported. The demand for mango in the world market is increasing day- by- day. It is reported that the markets for mangoes have increased in temperate countries because of social changes, promotion of fruit trade in developing countries and accessibility to international air cargo space. The expansion of mango trade has been possible because of successful post harvest management strategies to control diseases and insects (Rowlands, 2008).

Quality is a basic post-harvest requirement of a food process engineer and scientist for emerging food products. The quality assurance programme as reflected in chemical composition of foods is often determined to establish the acceptability or nutritive value of food product. These chemical properties include moisture content, crude protein, crude fat, food energy, fibre, ash and mineral. The moisture assay is vital because water is an expensive filler and it is a quality factor in preservation. An accurate and precise quantitative analysis of other chemical properties of foods is important for nutritional labeling and to determine whether the food meets standard of identity and is uniform

Mango is a very popular tropical fruit in the Ethiopia but is seasonal in nature. Due to this property, it is desirable to process it for future use. The result of the study on manufacturing of mango juice will inspire mango growers because it will add to the marketability of their product. Likewise, it may add income to the homemakers who would like to undertake processing. Furthermore, homemakers, researchers and extensionists will find more information for their work.

Mango powder is generally required for certain food products like ice cream, yoghurt, mango fruit bar, mango cereal flakes, mango cake and mango for their production. Therefore, there is a great need to develop a non-caking and soluble / readily mixing mango flakes / powder (Chattopadhyay, 1996).

Key challenges for developing a fruit processing sector in Ethiopia include:

- ✓ Lack of technical knowledge in processing
- ✓ Low level of technical support for maintenance

- ✓ Low capital base from which to invest
- ✓ Many low priced mango juice imports

### 2.3.4 Banana

Banana plants are monocotyledonous perennial and important crops in the tropical and subtropical world regions (Strosse *et al.*, 2006). They include dessert banana, plantain and cooking bananas. Traded plantain (*Musa paradisiacal* AAB) and other cooking bananas (*Musa* ABB) are almost entirely derived from the AA·BB hybridization of *M. acuminata* (AA) and *M. balbisiana* (BB) (Stover ,1987; Robinson ,1996). Plantain and cooking bananas are very similar to unripe dessert bananas (*M. 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 ( Emaga *et al.*, 2007). Dessert bananas are consumed usually as ripe fruits; whereas ripe and unripe plantain fruits are usually consumed boiled or fried (Surga *et al.*, 1998).

Table 2.5 Annual productions of banana fruit in Ethiopia

Production year	Amount (quintal )
2003/2004	1,751,497
2004/2005	1,818,293
2005/2006	2,114,498.71
2006/2007	2,279,421.21
2007/2008	2,610,592.27
2008/2009	1,943,331

Source: CSA,2009

#### 2.3.4.1 Nutritional Values of Banana

Banana is a well known source of carbohydrates and dietary fibre. Bananas have long been recommended as dietary supplements for individuals suffering from digestive disorders. According to (Mota *et al.* ,(2000), green banana fruit contain higher hemicelluloses content (6.08%) than most fruits and vegetables. Apart from dietary fibre, green bananas contain high amount of essential minerals such as potassium, and various vitamins such as A, B1, B2 and C (Chandler, 1995).

Bananas contain significantly high in potassium (400mg/100g pulp) and trace amount of sodium (1mg) and iron (Stover, 1987). They also have similar levels of B vitamins thiamine, niacin and riboflavin. Plantain has greater amount of vitamin A than bananas.

Plantains are rich in vitamin C, providing approximately 20mg for every 100g of flesh which is higher than banana (10mg/100g) (Chandler, 1995). Because of the low lipid and high energy value, bananas are recommended for obese and geriatric patients (Gasster, 1963). Bananas are useful for persons with pepticulcer, for treatment of infant diarrhea, in celiac disease and in colitis (Seelig, 1969).

Table 2.6 Nutrient composition of banana per 100g edible portion of raw banana fruit

NO	component	Value
1	Water(%)	68.6-78.1
2	Food energy(kcal)	65.5-111
3	Protein (g)	1.1-1.87
4	Fat(g)	.016-0.4
5	Total carbohydrate(g)	19.33-25.8
6	Fiber(g)	0.33-1.07
7	Ash(g)	0.60-1.48
9	Calcium(mg)	3.2-13.8
10	Phosphorus(mg)	16.3-50.4
11	Iron(mg)	0.4-1.50
15	Thaimine(mg)	0.04-0.54
16	Niacine(mg)	0.60-1.05
17	Ascrobic acid(mg)	5.60-36.4

Source: Morton, (1987)

Banana is one of the rare fruits which satisfy the definition of a good food i.e., one that contains an ample proportion of nutritive constituents which are easily digested and absorbed, while available at reasonable cost. It is one of the most easily assimilated fruits. From the nutritional point of view, banana has a calorific value ranging from 67 to 137 calories per 100 g and is closely comparable with potatoes but digested more easily .The average composition of banana fruit is as follows according to Gopalan, *et al.*(1980).

### 2.3.4.2 Banana powder

#### ❖ Product description

Chiquita Banana Powder is a free flowing product made from fresh bananas ripened to full flavor. This product is 100% natural without any preservatives or additives. Chiquita Banana Powder is easily used in diverse applications to enhance flavor whenever low moisture is necessary. It can be reconstituted in hot or cold liquid with a weight relation of 3:1 (water to banana powder) (Chiquita,2005).

#### ➤ Product characteristics

Table2.7 Product characteristics of Chiquitta banana powder

Product microbiological characteristics	
Moisture (%)	4.1
Color	Creamy to straw yellow color
Flavor	Ripe banana,free offflavors
Granulometry (max retained in mesh)	10%
Total plate count	<500
Coliform	Negative
Yeast and Mold(cfu/g)	<100
Salmonella	Negative

Source: Chiquita,2005

### **2.3.5 Fruit Drying Technology**

Drying is defined as the application of heat under controlled conditions to remove the majority of water normally present in a food by evaporation. The main purpose of drying is to extend the shelf life of foods by a reduction in water activity. This inhibits microbial growth and enzyme activity, but the processing temperature is usually insufficient to inactivate. Drying causes deterioration of both the eating quality and the nutritional value of food. The design and operation of dehydration equipment aim to minimize these changes by selection of appropriate drying conditions for individual food items (Elias, 2007).

#### **2.3.5.1 Drying Techniques**

The drying of materials whether solids, liquids or slurries to improve storage life or reduce transportation costs is one of the oldest and most commonly used unit operations. Drying of fruit, meat and various building and craft materials date back before the discovery of fire. The physical laws governing drying remain the same, even though the machinery to accomplish it has improved considerably. Today, dryers are in operation in most manufacturing industries including chemical, pharmaceutical, process and food. Products that are dried range from organic pigments to proteins, as well as minerals to dairy products. Because of the spectrum of duties required, there is a great variety of dryers available. The correct choice depends on the properties of the feed material and the desired characteristics of the final product. Several types of dryers and drying methods, each better suited for a particular situation, are commercially used to remove moisture from a wide variety of food products including fruit and vegetables. While sun drying of fruit crops is still practiced for certain fruit such as prunes, figs, apricots, grapes and dates, atmospheric dehydration processes are used for apples, prunes, and several vegetables; continuous processes as tunnel, belt trough, fluidized bed and foam-mat drying are mainly used for vegetables. Spray drying is suitable for fruit juice concentrates and vacuum dehydration processes are useful for low moisture / high sugar fruits like peaches, pears and apricots.

Factors on which the selection of a particular dryer/ drying method depends include:

- form of raw material and its properties
- desired physical form and characteristics of dried product
- necessary operating conditions;
- operating costs.

Table 2.8 Common dryer types used for liquid and solid foods.

Dryer type	Usual food type
Air convection dryers	
Kiln	Pieces
Cabinet, tray or pan	Pieces ,purees ,liquids
Tunnel	Pieces
Continuous conveyor belt	Purees ,liquids
Belt trough	Pieces
Air lift	Small pieces ,granules
Fluidized bed	Small pieces ,granules
Spray	Liquid ,purees
Drum or roller dryers	
Atmospheric	Purees ,liquids
Vacuum	Purees ,liquids
Vacuum dryers	
Vacuum shelf	Pieces ,purees ,liquids
Vacuum belt	Purees ,liquids
Freeze dryers	Pieces ,liquids

Source :Potter,1984

### 2.3.5.2 Process development for the preparation of fruit juice powder

Conversion of fruit juice/pulps in to free flowing powders ensures both shelf stability and convenience of use as ready to serve beverages at house hold, or also used any other product requiring fruit solids, such as ice creams, fruit custards, yoghurt, infant formulations, pharmaceutical products etc. The main advantages of fruit juice powders are to increase the shelf life, reduction of volume, reduce packaging and transportation cost, and convenience. Though fruit juice powders can be prepared by several methods of dehydration, such as hot air drying, vacuum shelf drying, freeze drying and spray drying etc. The main constraints encountered during dehydration of fruit juice or fruit juice concentrate are hygroscopicity, lump formation, thermo plasticity, loss of natural aroma and poor storage stability. Hence a different approach is needed.

### 2.4 Spray drying

The development of spray drying equipment and techniques evolved over a period of several decades from the 1870s through the early 1900s. The first known spray dryers used nozzle atomizers, with rotary atomizers introduced several decades later. Because of the relatively unsophisticated designs of the early spray dryers and practical difficulties in operating them continuously, very little commercial use of the process was made until the 1920s.

By the second decade of the twentieth century, the evolution of spray dryer design made commercial operations practical. This process found its earliest widespread acceptance in dairy industry. Milk drying was the first major commercial application of the technology. Spray dryers to produce powdered milk, whey and baby formulas are still one of the largest applications of the technology.

Spray drying is not a new technology as far as the pharmaceutical industry is concerned, having been used successfully for producing drug substances and various excipients since the early 1940s. It was employed primarily in manufacturing of bulk pharmaceuticals and fine chemicals, such as antibiotics, analgesics, antacids, and vitamins (Kloyjai, 2009).

Spray drying encapsulation has been used in the food industry since the late 1950s to provide flavor oils with some protection against degradation / oxidation and to convert liquids into powders. Spray drying was developed as a convenient method of drying heat-sensitive biological materials, such as enzymes and pharmaceutical proteins, with minimal loss of activity. Spray drying came of age during World War II, with the sudden need to reduce the transport weight of foods and other materials. This surge in interest led to developments in the technology that greatly expanded the range of products that could be successfully spray dried. It has been used in pharmaceutical technology studies to produce pharmaceuticals excipient with improved compressibility, such as lactose, to improve flow properties, to prepare free-flowing granules for tablet production, to improve the drug aqueous solubility and, consequently, their bioavailability. In addition, a number of formulation processes can be accomplished in one step in a spray dryer; these include complex formation and micro encapsulation. The fact that spray drying greatly reduces the labor-intensive formulation, drying and granulating of solid-dose pharmaceuticals gives cause to review the potential for this process in numerous instances. The pharmaceutical industry, however, is coming under ever-increasing pressure to reduce manufacturing cost, while still maintaining strict purity standards and highest level of quality control.

#### **2.4.1 Spray Drying processes**

Spray drying is a dehydration process in which a concentrated solution, suspension, emulsions or pump able paste is sprayed, dried and collected. The particles are dried while they are suspended in the hot drying media. The dried products can be in the form of powder, granules or agglomerates depending on physical and chemical properties of the feed, the drier design and the drying operation (Masters, 1972). There are four processes in spray drying including atomization of the feed into a

spray; mixing of the spray and drying medium (air); drying of the spray or evaporation; and product recovery by separation of product and air (Masters, 1972; Marshall, 1954).

#### 2.4.1.1 Atomization of Liquid Feed in Drops

The principle of atomization consists in giving energy to the liquid to form a thin liquid film and to break it in a large number of drops to increase the exchange surface available for heat and mass transfers with drying air. By decreasing the drop size from 1 mm to 10  $\mu\text{m}$ , the total spray surface is multiplied by 100 (Table. 2.9).

Table 2.9 Total spray exchange surface depending on drops diameter for a fixed sprayed volume of  $1\text{m}^3$  (Mujumdar ,1995).

Total Volume ( $1\text{m}^3$ )	Droplet diameter (m)	Number of droplets	Droplet Surface $A_{\text{drop}}(\text{m}^2)$	Total spray surface $A_{\text{tot}}(\text{m}^2)$
1	1.234	1	3.14	3.14
1	$1 \times 10^{-2}$ (1cm)	$1.986 \times 10^6$	$3.14 \times 10^4$	623.6
1	$1 \times 10^{-3}$ (1mm)	$1.986 \times 10^9$	$3.14 \times 10^{-6}$	62.36
1	$1 \times 10^{-4}$ (100 $\mu\text{m}$ )	$1.986 \times 10^{12}$	$3.14 \times 10^{-8}$	62.360
1	$1 \times 10^{-5}$ (10 $\mu\text{m}$ )	$1.986 \times 10^{15}$	$3.14 \times 10^{-10}$	62.3600

#### ❖ Rotary atomizer

A rotary (or wheel) atomizer consists of two circular plates (top and bottom) with radial vanes (straight or curved) or bushings between them. The liquid feed enters in the centre, accelerates across the vanes forming a thin film of liquid that is ejected at the wheel peripheral speed and readily disintegrates into droplets forming a wide jet with an “umbrella” shape; initial trajectory is almost horizontal. Typical peripheral speed for rotary atomizers varies from 100 to 200 m/s. The rotary atomizer can be moved by compressed air (pilot equipments) or by an electrical engine. The characteristics of the liquid spray depend on the peripheral speed and geometry of the rotary atomizer, on the flow rate and physical properties of liquid (King et al., 1984).

#### ❖ Pressure nozzle

With a pressure nozzle (Fig. 2.1) the spray is created by the conversion of the pressure energy applied to the liquid into kinetic energy giving, at the same time, a rotary motion to the thin liquid film. The liquid is forced through an orifice by a high pressure pump (5-7 MPa). It enters tangentially in the nozzle and exits from the orifice (diameter = 0.4 to 4 mm) forming a cone having an angle in the range of 40°-140°. The pressure nozzle leads to the formation of a spray more homogeneous in terms of drop size distribution than the one produced by a rotary atomizer. The

applied pressure influences the angle of the cone and the drops size, which can be estimated with empirical correlations like the following (Mujumdar, 1995).

Table 2.10 Typical droplet size, maximum liquid feed flow rate and energy consumption of several kinds of atomizers(Mujumdar ,1995)

Atomizer	Range of drop size( $\mu\text{m}$ )	Liquid folw rate ( $\text{kg.h}^{-1}$ )	Energy consumption ( $\text{kJ for } 1000 \text{ kg.h}^{-1}$ )
Rotary wheel	1-600	<2000	25.0
Pressure nozzle	10-800	<100	2.5 (3-5MPa)
Pneumatic nozzle	5-300	<1000	40.0 (air 0.3MPa;0.5-0.6 $\text{m}^3.\text{kg}^{-1}$ )
Sonic bozzle	5-1000	-	

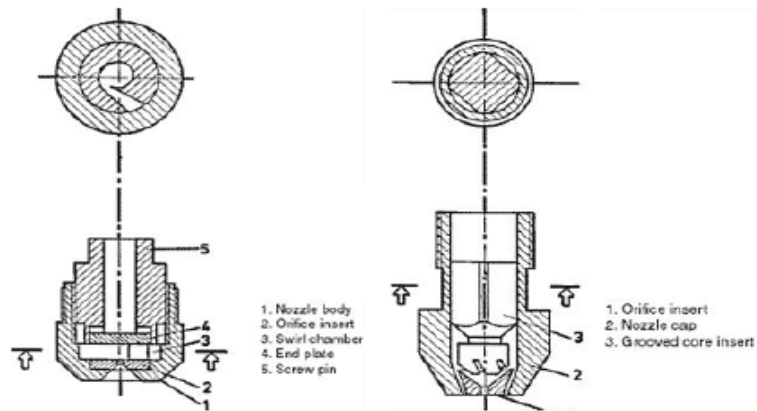


Figure2.1. Pressure nozzle (Pisecky, 1997)

#### ❖ Pneumatic nozzle

The pneumatic (or two-fluid) nozzle uses compressed air (or steam) to atomize the liquid. Mixing between liquid feed and atomizing air can be internal or external (Fig. 2.3). In some spray drying towers, the two-fluid nozzle is installed in the bottom of the chamber (Fig. 2.4) and depending on the atomizing air pressure the liquid can be sprayed at different heights inside the chamber (“fountain” nozzle).

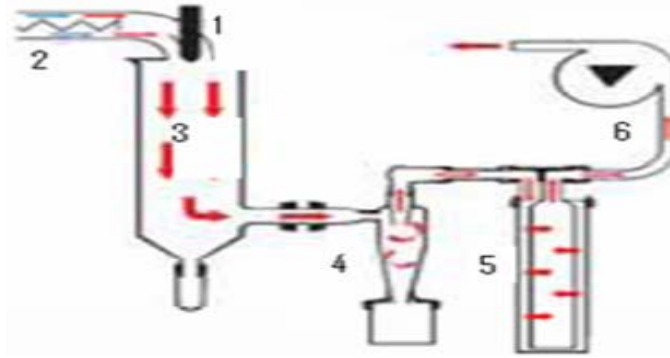


Figure 2.2 Possible spray drying installation

Source Mini spray dryer B-290

1. Two fluid nozzle, operated by compressed air to disperse the solution into fine droplets
2. Electric heating of the drying medium
3. Spray cylinder for drying the droplets to solid particles
4. Separation of the particles in the cyclone
5. Outlet filter to remove fine particles
6. Aspirator for generating the flow

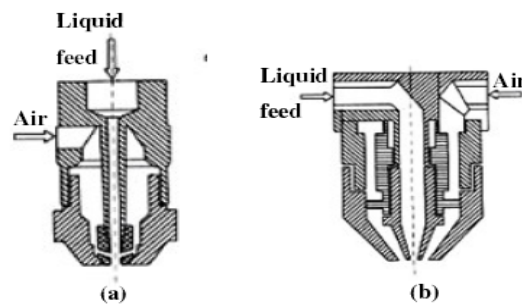


Figure2.3. Two-fluid nozzle with (a) internal air/liquid mixing and (b) external mixing (Pisecky, 1997)

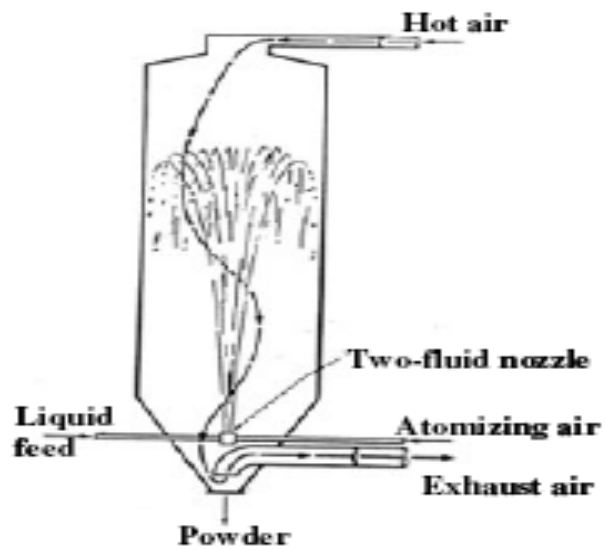


Fig2.4. Spray drying chamber with fountain two-fluid nozzle (Mujumdar, 1995)

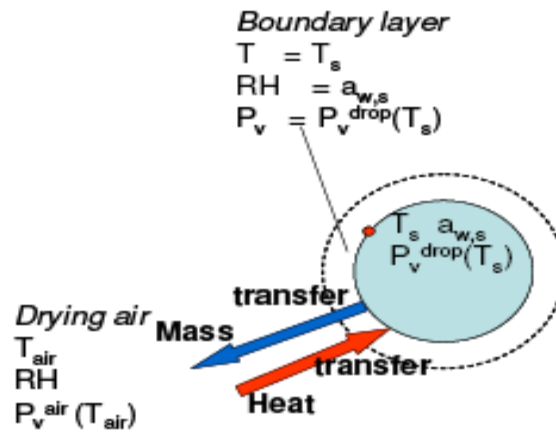


Figure 2.5 Convective drying of a liquid drop; heat and mass transfers between drying air and drop surface through the boundary layer

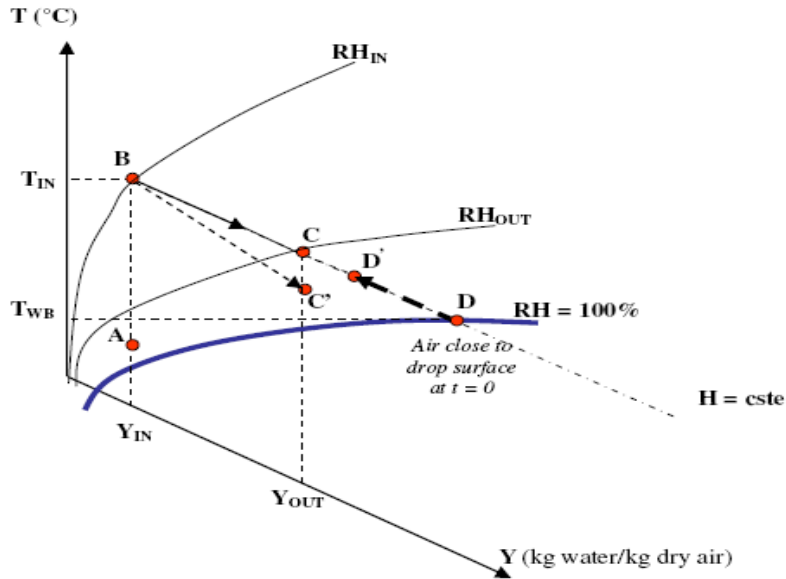


Figure 2.6. Mollier diagram - Air temperature and relative humidity evolution during spray drying.

Pneumatic nozzles are used to produce sprays in which the drops diameter can be changed by varying the air/liquid ratio. With two-fluid nozzles it is possible to maintain the same drop size distribution when changing the liquid flow rate, by adjusting the compressed air flow rate. The main disadvantage of this kind of atomizer is the cost of compressed air (or steam). Due to the compact shape of the spray from nozzles compared to the rotary atomizer spray, it is easier to measure directly the drops size by laser diffraction by performing some spray experiments outside the dryer chamber (Jimenez, 2007).

#### ❖ Sonic nozzle

Some liquid feed as non-newtonian liquids or highly viscous materials cannot be atomized with rotary wheel or pressure nozzles. For this reason attention has been paid to the development of a different atomization technique using sonic energy (Sears and Ray, 1980; Upadhyaya, 1982). The break-up of liquid occurs in the field of high-frequency sound created by a sonic resonance cup placed in front of the nozzle.

#### 2.4.1.2 Mixing of Spray and Drying medium

The feed is atomized directly into the hot air stream. As the droplets pass through the hot air flow, the moisture evaporates rapidly. The time and distance required to complete the drying of the droplet spray depends on the rate of heat and mass transfer between the droplets and the drying medium (Crowe, 1971). Heat and mass transfer during drying occur in the air and vapour films

surrounding the droplet. There is the protective envelope of vapour, which keeps the particle at the saturation temperature and, as long as the particle does not become completely dry, evaporation still takes place. Thus, heat sensitive products can be spray dried at relatively high air temperatures without being damaged.

#### **2.4.1.3 Evaporation**

At the evaporation stage, the concentration difference of the vapour at the droplet surface and in the drying gas is the driving force for mass transfer. A higher drying gas temperature causes higher rates of heat transfer to the droplet. Heat transfer is essential to provide the energy for evaporation which, in turn, establishes a vapour concentration gradient for mass transfer. Then the mass transfer results in size reduction and/or changes in the density of the droplet material which affect the droplet motion (Crowe, 1971). All transfer mechanisms are interactive precluding the development of simple analytic expression to describe the variation of droplet properties throughout the entire drying period. Evaporation in the spray dryer is almost instantaneous; the drying medium temperature undergoes rapid reduction and the dried material is not raised above this terminal medium temperature. The extremely high evaporation rates obtainable in spray drying are due to high ratio of surface area to mass of the droplets produced in the atomizing device (William-Gardner, 1971). Drying chamber design can create optimum air flow conditions and provide sufficient residence time for the particle formation and drying to be completed (Masters, 1994).

#### **2.4.1.4 Separation of Dried Product**

Separation of dried product from the air is the final phase of spray-drying. After evaporation, the large particles fall to the bottom of the chamber and are collected while the fine particles are entrained with the exhaust air and are generally collected by passing the air through a series of external cyclones, electrostatic precipitator, scrubbers or bag filters. Fines are bagged or returned to an agglomeration process in the drier (Masters, 1994).

#### **2.4.2 Physical Changes of Food Droplet During Spray Drying Process**

As explained earlier, heat and mass exchange occur while droplets are travelling in the hot air. At the initial phase of evaporation, the temperature, and the evaporation rate change rapidly but the droplet soon achieves a constant evaporation rate (Vehring *et al.*, 2007). The temperature of particle approaches the wet bulb or saturation temperature of the drying air. During spray drying, the glass transition temperature of the atomized product increases as the water content is reduced. When the temperature of the droplet is above  $T_g$ , it influences the structural characteristics of the product.

### 2.4.3 Drying of drops in air for co-current spray dryer

Spray drying is a convective drying process in which hot air provides energy for evaporation of solvent (usually water) from liquid drops, inside the limited volume of a chamber. In concurrent dryer, just after drop formation by atomization, drops are in contact with inlet air. Drops and air move together and exchange heat and water. The water vapor is transferred from drop surface to surrounding air through the air boundary layer surrounding each particle (Fig. 1.10). As a consequence, drops/particles are drying and air is cooled and humidified while crossing the chamber.

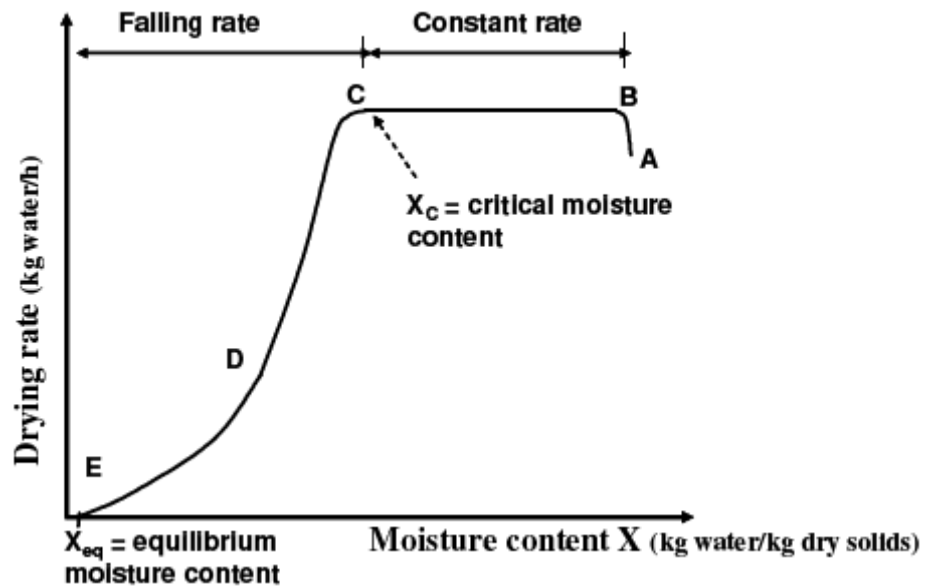


Figure 2.7 Evolution of drying rate of liquid drops (Alessandro, 2009) .

### 2.4.4 Spray Dried Powder Characteristics

The powders that are formed as a result of spray drying are unique due to both material composition and drying conditions. In addition to moisture content, some of the most important characteristics of spray dried powders include particle size, bulk density, and rehydration capability. Processing conditions including feed viscosity, solids concentration, temperature, and flow rate; the inlet and outlet drying air temperature; atomization technique, and flow pattern in the dryer have a dramatic effect on powder characteristics.

#### **2.4.4.1 Bulk Density and Particle Size**

As solids concentration in the feed increases, and consequently the feed viscosity increases, the particle size of the material will increase. Goula and Adamopoulos (2004) attributed an increase in particle size to an increased droplet size as feed viscosity increased for spray dried tomato paste.

With increased feed concentration, the bulk density has been reported to both increase and decrease depending on product and drying operation (Masters, 1991). Goula and Adamopoulos (2004) found a correlation between an increase in particle size and a decrease in bulk density for spray dried tomato paste. Banat *et al.* (2002) found bulk density to increase with increased feed concentration due to the formation of heavy, solid spheres with high density. Temperature of the feed has a variable effect on bulk density. If an increased feed temperature influences improved atomization to form spherical droplets, the bulk density will increase. However, if the feed is already easily atomized, increased feed temperature can lower bulk density. This variable is much dependent on the characteristics of the product (Masters, 1991). If a feed rate increase results in higher residual moisture content, the powder bulk density will also increase. Conversely, Banat *et al.*, (2002) found that particle size could increase and bulk density decrease with increasing feed rate as a result of an increased potential for droplets to collide and coalesce.

In addition to particle size and bulk density, the rehydration properties of dried powders are important. Most powdered foods are intended for rehydration and the ideal powder would wet quickly and thoroughly, sink rather than float, and disperse/dissolve without lumps. These instant properties of a powder involve the ability of a powder to dissolve in water. Rehydration can be divided into 4 steps: 1.) wetting, 2.) sinking, 3.) dispersing, and 4.) dissolving (Hogekamp *et al.*, 1996).

The effects of processing conditions and material composition on particle morphology are also important considerations in examining spray dried materials. In a study of the morphology of several spray dried products including foods, particles were categorized into 3 main morphologies: crystalline, skin forming, and agglomerate. These structures were found to be material specific and dependent on drying conditions. Most of the food products fell into the skin forming category. These particles formed a non-liquid continuous layer, polymeric in appearance.

#### **2.4.4.2 Stickiness and Glass Transition Temperature in Spray Drying**

Spray drying is a dehydration technique applied to many types of food products. These products can be generally categorized into sticky and non-sticky products. For non-sticky products such as skim milk, gums, and proteins, a simple dryer design can be used and the resulting powder is non-hygroscopic and free flowing. On the other hand, sticky products are difficult to spray dry because these materials stick to the walls of the drying chamber and may remain in a syrup form after the drying process. These material properties lead to operational issues, low yields, and caking during storage (Bhandari *et al.*, 1997).

The main food constituents which cause stickiness issues are sugars, organic acids, and fats as seen in products such as fruit juice, vegetables, honey, and amorphous lactose. High hygroscopicity, high solubility, low glass transition temperatures, and low melting point contribute to stickiness (Bhandari *et al.*, 2001).

#### **2.4.5 Spray Drying of Fruit Juice**

Among food-stuffs, fruit juice is the most difficult substance to be spray dried so as to retain as many as possible of the natural properties and qualities in the final powder such as colour, flavour, test and texture (Adhikari *et al.*, 2000; Bhandari *et al.*, 1993). Owing to the thermoplastic and hygroscopic nature characteristics of the fruit and vegetable powders special attention needs to be paid to the chamber design, the inlet and outlet temperature, total solid content of the fruit juice to be spray dried, a suitable drying aid, the handling of the dried particles and the packaging of the product after drying (Dolinsky *et al.*, 2000; Goula & Adamopoulos, 2003).

##### **2.4.5.1 Glass Formation in Spray Drying**

During the spray drying process, dehydration of the atomized liquid particles proceeds from the particle surface to the inner core. A layer of concentrated solutes is formed on the particles surface and there is a decrease in the particle temperature due to evaporative cooling. The extremely rapid removal of water increases the viscosity of the remaining solution. The particle surface may approach the glassy state before colliding with other particles or drier walls. Downton *et al.* (1982) found that a critical surface viscosity resulting in stickiness and caking is  $> 107$  Pa.s. The general accepted value for the viscosity of glassy materials is  $> 10^{12}$  Pa.s (Sperling, 2006, Roos, 2002, Allen, 1993) which is an ideal viscosity for non-sticky powders. The verifications of the particles surface in spray drying is essential in allowing the free flow of the particles through the drying chamber and avoiding caking of particles with each other and on the drier surfaces.

At the end of the drying process, the particle temperature and water content should support the solid, glassy state (Roos, 2002).

#### **2.4.5.2 Additives in spray drying**

Other than the operational techniques, such as cooling the drier wall and blowing with cold air, an additive or drying aid can be used to reduce stickiness during fruit juice spray drying (Kudra, 2002; Gupta, 1978). A drying aid is added for many purposes such as improving the drying rate, stickiness prevention, reducing hygroscopicity, maintaining flowability of the dry powder and maintaining quality of the powder in storage (Langrish et al., 2007).

There are many materials used as carriers. Tricalcium phosphate was used as a carrier in the concentrated extract of *Possiflora edulis* leaves (Linden et al., 2002). Soybean proteins, pectins and hemicelluloses have been used as structural element in powders (Bhandari et al., 1993). Maltodextrins at different dextrose equivalence values (DE) are the most common carriers in spray drying of fruit juice (Gupta, 1978; Masters, 1985; Roos 1995; Bhandari et al., 1997; Rodriguez-Hernandez et al., 2005; Langrish et al., 2007).

#### **2.4.6 Fruit and vegetable application**

Fruit juice powders have promising application in the food industry as value-added ingredients providing numerous functional and nutritional benefits. As an ingredient, these powders provide functionality in the food system as well as improving the health image of the product for consumers. Additionally, these powders offer the handling and storage benefits of dry ingredients along with the characteristics of the original juice (Francis & Phelps ,2003). Fruit powders can enhance the nutritional benefits of many products by contributing fiber, vitamins, minerals, or bioflavonoids. Their physico-chemical properties make them ideal for carrying fat and water soluble nutrients.

#### **Advantages of Spray Dried Powders:**

Spray drying does have many advantages, particularly with regard to the final product form. This is especially so where pressing grade materials are required, i.e., in the production of ceramics and dust-free products such as dyestuffs. With the introduction of new geometries and techniques, there has been further development into areas such as foods, and in the production of powders which may be easily reconstituted:

- Can be designed to virtually any capacity required. Feed rates range from a few pounds per hour to over 100 tons per hour.
- Powder quality remains constant during the entire run of the dryer.

- Operation is continuous and adaptable to full automatic control.
- A great variety of spray dryer designs are available to meet various product specifications.
- Can be used with both heat-resistant and heat sensitive products..
- Feedstock can be in solution, slurry, paste, gel, suspension or melt form.
- Nearly spherical particles can be produced.
- These spray dryers usually incorporate one or two fluid beds – static and vibrating – for the final drying and cooling of the agglomerated powder.
- Dry flavors are easier to handle in dry application than liquid flavors. Some applications of dry flavors are cake mixes, pudding powder, instant foods, beverage powders, high temperature products, etc.

#### **Disadvantages of spray drying**

- The equipment is very bulky and with the ancillary equipment is expensive.
- The overall thermal efficiency is low, as the large volumes of heated air pass through the chamber without contacting a particle, thus not contributing directly to the drying.

#### **2.5 General process description of mango and banana powder**

Dried or dehydrated fruits and vegetables can be produced by a variety of processes. These processes differ primarily by the type of drying method used, which depends on the type of food and the type of characteristics of the final product. In general, dried or dehydrated fruits and vegetables undergo the following process steps: predrying treatments, such as size selection, peeling, and color preservation; drying or dehydration, using natural or artificial methods; and post dehydration treatments, such as sweating, inspection, and packaging. Figure 2-1 shows a flow diagram for a typical fruit e dehydration process. In general, dried refers to all dried products, regardless of the method of drying, and dehydrated refers to products that use mechanical equipment and artificial heating methods (as opposed to natural drying methods) to dry the product.

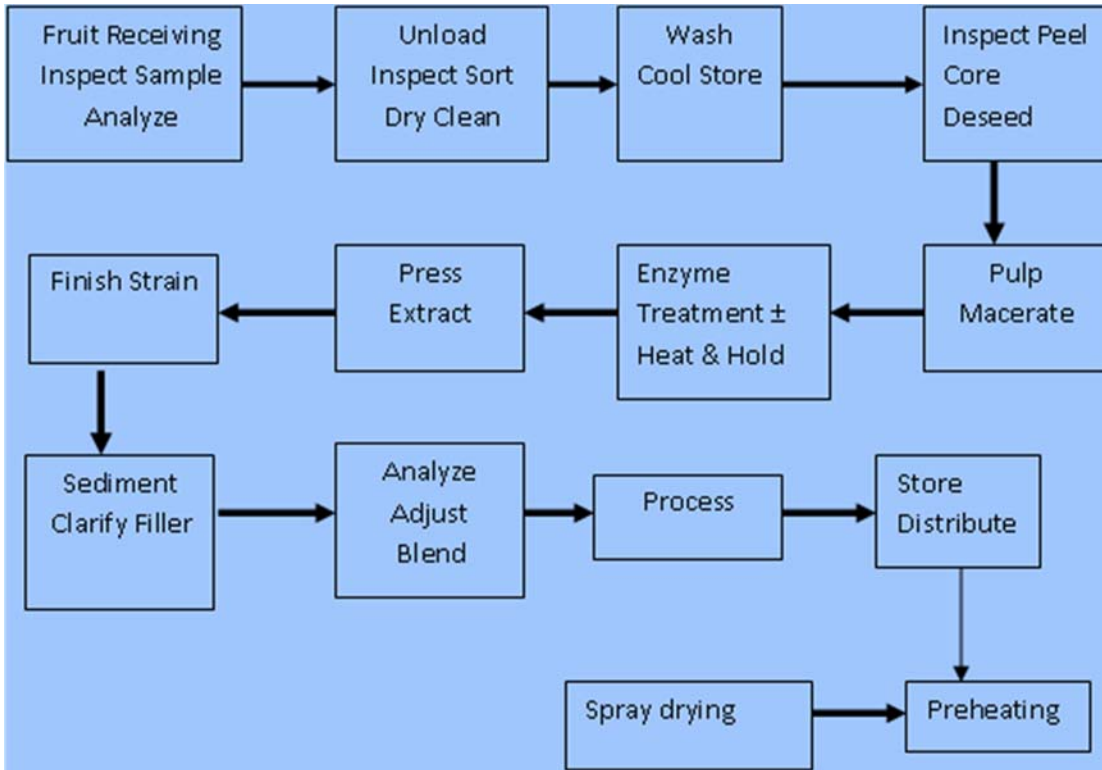


Fig 2.8 Flow chart of spray drying process

# **CHAPTER THREE**

## **MATERIALS AND METHODS**

### **3.1 Materials and Sample Preparation**

#### **3.1.1. Basic Raw Materials, Sources and Experimental Location**

The basic raw materials were improved mango variety (Tommy), local Arbaminch mango and local giant Cavendish banana. The improved mango (Tommy) variety was obtained from Upper Awash Agro- industry enterprise and the local Arbaminch mango and banana were obtained from the local market in Addis Ababa.

The experiment on spray drying process and product quality analysis were carried out in the Food Engineering laboratory of the Department of Chemical Engineering, Faculty of Technology, in Addis Ababa University. Laboratory analysis for proximate composition was conducted at Ethiopian Health and Nutrition Research Institute (EHNRI).

#### **3.1.2 Reagents and Solutions**

- Sodium thiosulphate
- Hydrochloric acid
- Ether
- Thiosulphate solution
- Hydrochloric acid
- Water free acetone
- Potassium iodide

### 3.1.3 Instrumentation

- BÜCHI Mini Spray Dryer B-290
- Abbe Refractometer
- Flasks, measuring apparatuses, test tubes
- Beaker, watch glass, stirrer
- Sintered glass crucible
- Vacuum pump
- SV-10 Vibroviscometer
- Oven
- Muffle Furnace
- Pyknometer
- Kjeldah
- Digestion apparatus
- Digestion tubes
- Tecator distillation apparatus
- Digestion apparatus (aluminum block, tubes, etc)
- Soxhlet extraction apparatus
- Condenser
- Extraction flask
- Extraction flask, extraction thimble
- Electric hot plate
- Fruit/vegetable grinder
- Weighing and measuring equipment
- Stainless steel pan
- Heat source Thermometer

### **3.1.4. Sample Preparation**

#### **3.1.4.1 Preparation of Fruit Juices and powder**

The mangoes and bananas selected manually according to their appearance. The damaged and spoiled fruits were discarded. The fruits were separated for preliminary studies and drying experiments.



Fig3.1. Ripened mango



Fig3.2. Ripened banana

The ripened, with tight skin mango fruit were selected and were washed thoroughly in warm water to remove gummy and foreign materials. The skin of the fruits was peeled manually by knives. The flesh portions were chopped and pulped by pulper. The mango pulp was diluted with water by 1:1 ratio on weight basis (Bachtair and Sarmidi, 1997). The pulp was then thoroughly mixed by a mechanical stirrer and filtered by 150 micron cloth filter to remove fibers from the pulp to make it suitable for atomization. The banana pulp was also prepared in the same procedure as the mango pulp except the blanching process. Before pulping banana, the raw banana fruits were dipped in hot water for 5 min, peeled and chopped. Thereafter the blanched banana was pulped, diluted with water 1:2 ratio on weight basis and filtered (Mani,2002).

Generally the production of mango and banana powder involved cleaning, peeling, stone removal, chopping, pulping, dilution, filtration and spray drying. One kilogram of mango could produce about 0.230 kg of powder having 4% moisture content. Where as one kilogram of banana could produce about 0.1 kilogram of powder having 2.8% moisture content.



Fig3.3 Mango pulp preparation

#### **3.1.4.2 Setting up of the Spray Drier**

A laboratory scale Buchi mini spray dryer ( model BÜCHI Mini Spray Dryer B-290) with a 0.6 5m diameter x 1.1 m high chamber, 0.7 mm nozzle tip diameter pneumatic (or two-fluid) were used in the experiment. Compressed air supply was provided at a pressure of 5-8 bars. Aqueous mixtures containing 12% and 15% total solids of mango and banana juice, respectively were concentrated to 55% , 50% and spray dried and the powder was collected by a cyclone. Based on identified thermal efficiency, two inlet temperatures were used in the experiments, namely 200 and 210°C for mango powder production as well as 170 and 180°C for banana powder for optimum yield , moister content and acceptable nutritional value. The outlet temperature was set automatically by the instrument based on feed rate.

The feed flow rate for the spray dryer was set at 12 and 15% for mango and for banana juice respectively. The constant operational conditions were: concentration of at 55% for mango juice and 50% for banana juice (Mani, 2002), aspirator rate and spray air flow of 100% and 30m<sup>3</sup>/h respectively.

### 3.1.4.3 Spray drying process

The experiment was initiated by the spray dryer efficiency for mango and banana juice powder production via variation of parameters like inlet temperature and flow rate at constant concentration, aspirator flow rate (quantity of air) and peristaltic pump flow rate. According to Bachtair and Sarmidi (1997) the outlet temperature depend up on the flow rate of the material to be feed. Efficiency of the spray dryer can be improved by widening the gap between the inlet and outlet temperatures. Increasing the differences between inlet and outlet air temperature increases the thermal efficiency of the spray drying operation, which can be expressed as described in Mujumdar (1995). This reduces the specific heat consumption of the process. Because a smaller mass of gas is required to achieve a given amount of drying; and this gas, which leaves at a temperature substantially independent of the inlet temperature, carries with it less heat than mass of gas is used when temperature is lower. The inlet temperature of hot air ranges between 160-300<sup>0</sup>C and the outlet temperature is between 80-134 °C (Bachtair and Sarmidi, 1997). The efficiency of the spray dryer can be calculated as:

$$\eta = \frac{\text{Heat used}}{\text{Heat supplied}}$$
$$\frac{MC_p (T-T_f)}{MC_p (T-T_a)}$$

Where T = The inlet temperature, °C

$T_f$  = The final exhaust temperature, °C

$T_a$  = Ambient temperature, °C

$C_p$  = Specific heat capacity of juice J/kg.k

M = Mass of juice, kg

By indentifying the optimum parameter range, spray drying process continued until the maximum yield and the required moisture content were obtained by varying temperature and flow rate alternatively. The Mini laboratory spray Dryer B-290 was used to produce free flowing mango juice and banana juice powder. The performance of the spray dryer is given below.

**a) Mango powder production**

- Feed flow rate (%): 15& 12
- Air flow rate (kg dry air/h): 30
- Feed temperature (°C ): 60
- Air inlet temperature (°C): 200&210
- Concentration 55%.

The production of mango powder involved cleaning, peeling, stone removal, chopping, pulping, dilution, filtration and spray drying.

**b) Banana powder production**

- Feed flow rate (%): 15& 12
- Air flow rate (kg dry air/h): 30
- Feed temperature (°C ): 60
- Air inlet temperature (°C): 170&180
- Concentration 50%

The processing of banana into banana powder involved as dipping in warm water, peeling, slicing, blanching, pulping, dilution and filtering. The filtered banana juice was spray dried to get the banana powder. The total solid content of feed used for atomization was very low. The solid content of banana juice should be increased by homogenization.

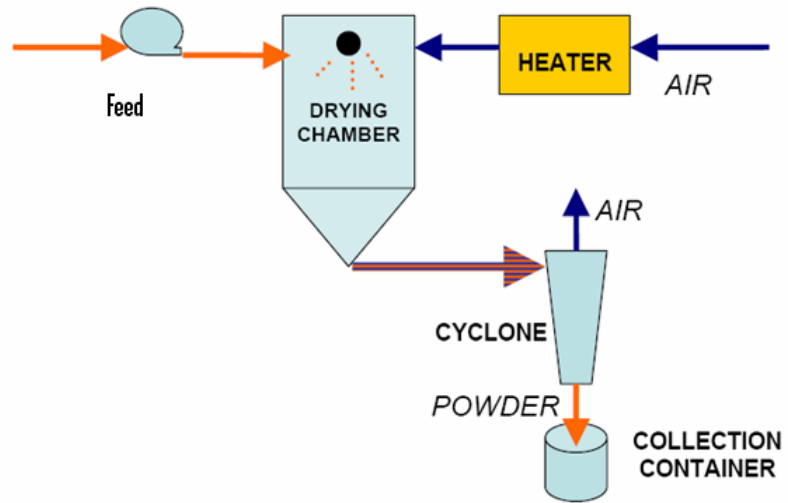


Fig3.4. Spray drying process



Fig3.5. Buchi mini-Spray dryer

### 3.2 Estimation of Drying Periods for Fruit Powders

The two types of drying rate for any droplets in spray drier. These are constant rate period and falling rate period.

The drying period for the droplet was calculated by using the following formula

$$t_c = \frac{\lambda \rho_w (D_o - D_c)^2}{8 K_a (T_a - T_w)} \text{----- [1]}$$

$$t_f = \frac{\lambda \rho_d (D_c)^2}{6 K_a (T_a - T_w)} (W_c - W_f) \text{----- [2]}$$

Where  $\lambda$  : Latent heat of air (J/kg)

$\rho_w$  : Density of fruit purees (kg/m<sup>3</sup>)

$D_o$  : Initial droplet diameter (m)

$D_c$  : Critical droplet diameter (m)

$\rho_d$  : Density of dried fruit powder (kg/m<sup>3</sup>)

$T_a$  : Dry bulb temperature (°C)

$T_w$  : Wet bulb temperature (°C)

$K_a$  : Thermal conductivity of air (W/mk)

$t_c$ : constant rate period(s)

$t_f$ : Falling rate period(s)

$W_c$ : Critical moisture content (%)

$W_f$ : Final moisture content (%)

### 3.3 Physico-Chemical Analysis of Mango and Banana Juice and Powder

Analyses of the mango and banana juice were carried out to determine, bulk density, pH, total soluble solid, viscosity, moisture content, crude protein, crude fat, crude fiber total ash and vitamin C content. The spray-dried powders were analyzed for their solubility, bulk density, pH, Viscosity, moisture content, crude protein, crude fat, crude fiber total ash and vitamin C content.

#### 3.3.1 Proximate Analysis

All analytical measurements were carried out in duplicate. Determination of moisture content, crude fat, crude protein, total ash and crude fiber of mango, banana puree and powder were determined as described in the AOAC (2000).

##### a) Determination of moisture content (AOAC 2000, 925.05)

A Dish was dried at 130°C for one hour and was placed in a desiccator for about 15-20 minutes. The mass of the dish was measured ( $W_a$ ). About 2-3g of the sample was weighed into the moisture dish ( $W_i$ ). The sample was dried at 130 °C for one hour or at 100 °C for 6 h. After drying is completed, it was measured as  $W_f$ .

$$MC_{wb} = \left[ \frac{(W_i - W_f)}{(W_i - W_a)} \right] \times 100$$

Where:

- $MC_{wb}$  is the moisture content in wet basis (%)
- $W_i$  is the initial weight of samples before drying plus aluminum dish and lid (g)
- $W_f$  is the final weight of dried samples plus aluminum dish and lid(g) and
- $W_a$  is the weight of aluminum dish and lid(g)

##### b) Determination of dietary (crude) fiber in food samples (AOAC 2000, 920.169)

About 2g of the sample was weighed. If the sample contains fat >1%, the fat was extracted by hexane. The defatted sample was transferred in to 600ml beaker. Fiber contamination from paper or brush is avoided. 0.25-0.5g bumping granules, followed by 200ml 1.25% sulfuric acid solution was added to the beaker near-boiling. The sample in the beaker was boiled for 30 minutes by rotating periodically. Near the end of refluxing, it was placed on Buchner funnel fitted with No.9 rubber stopper and filtered. At the end of filtration, the solids were washed by warm water and 1.25% sodium hydroxide. The filtration was continued until dryness. The residue was placed on crucible. The crucible was dried for two hours at 130 °C or overnight 110 °C. Then it was cooled in the

desiccator and weighed ( $W_1$ ). Then again it was ashed at  $550^\circ\text{C}$ , cooled in a desiccator and weighed ( $W_2$ ).

$$\text{Crude fiber (\%)} = \frac{W_1 - W_2}{\text{Weight of sample}} \times 100\%$$

Where:  $W_1$ - Weight of crucible and residue(g)

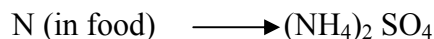
$W_2$  - Weight of crucible and ash(g)

### C) Crude protein determination

#### ➤ Kjeldahl method of crude protein analysis (AOAC 2000, 979.09)

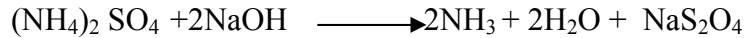
##### Digestion

About 0.1-1g of the food sample was weighed on an analytical balance into the digestion flask (round- bottom flask with a long neck, similar in appearance to a volumetric flask except for the round bottom and the lack of a calibration line) or larger test tube. Then the sample was digested by addition of small volume (3-5ml) of concentrated  $\text{H}_2\text{SO}_4$  (an oxidizing agents which digests the food), anhydrous  $\text{Na}_2\text{SO}_4$  or  $\text{K}_2\text{SO}_4$  that speed up the reaction by raising the boiling points of  $\text{H}_2\text{SO}_4$  and a catalyst ( $\text{CuSO}_4$ , selenium, titanium or mercury) to speed the reaction. About 1 g of catalyst mixture was made of  $\text{Na}_2\text{SO}_4$  or  $\text{K}_2\text{SO}_4$  with anhydrous  $\text{CuSO}_4$  in the ratio of 10:1 used. Digestion converted any nitrogen in the food (other than that which is in the form of nitrates or nitrites) into ammonia and other organic matter to  $\text{CO}_2$  and  $\text{H}_2\text{O}$ . In acidic solution, ammonia was not liberated as gas because rather it exists as ammonium sulfate salt.



## Distillation

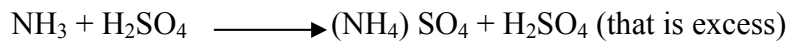
After digestion had completed, the content in the flask was diluted by water and a concentrated NaOH (40%) solution. It was added to make the solution slightly alkaline and to liberate ammonia gas.



The ammonia was then distilled into receiving flask that consist a standardized strong acid such as solution of excess boric acid (4%) or sulfuric acid for reaction with ammonia or sulfuric acid.

## Titration

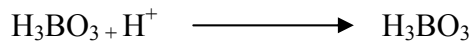
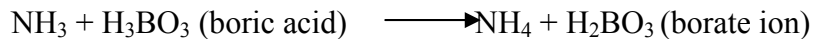
If  $\text{H}_2\text{SO}_4$  was used in the receiving flask, the excess acid was back titrated with NaOH.



(Back titration reaction)



But if boric acid was used, the borate ion was titrated with standard acid (0.1N HCl).



Calculation: Total nitrogen, percent by weight

$$= \frac{(T-B) * N * 14.007 * 100}{W}$$

Where; T= Volume in ml of the standard sulphuric acid solution used in the titration for the test material

B: Volume in ml of the standard sulphuric acid solution used in the titration for the blank determination

N: Normality of standard sulphuric acid

W: Weight in grams of the test material

**d) Crude Fat content determination (AOAC 2000, 4.5.01)**

Fat content was determined using AOAC (2000), fat is extracted with Ether (peroxide free) from dried samples in a soxhlet apparatus, and the other is evaporated from the extraction flask. The amount of fat is calculated from the difference in weight of the extraction flask before and after extraction.

➤ **Soxhlet fat extraction method**

About 3-4 g of sample was weighed and put into a thimble lined with a circle of filter paper. The thimble with contents was placed into a 50ml beaker and dried in an oven for 2 h at 110<sup>0</sup>C. Thimble content was transferred in to extraction apparatus. The beaker was rinsed for several times with the solvent hexane. The sample contained in the thimble was extracted with the solvent hexane in a Soxhlet extraction apparatus (2055 soxtec, swiden) for 6-8 hours at a condensation rate of at least 3-6 drops per second.

At the completion of the extraction, the extract was transferred from the extraction flask into a pre-weighed evaporating small beaker (150-250ml) with several rinsing with the solvent. The hexane was evaporated until no odor was detected. The beaker and contents was dried in an oven for 30 minutes at 100<sup>0</sup>C. Then it was removed from the oven and cooled in a desiccator. The beaker and contents were weighed.

Formula:  $W = W_2 - W_1$

$$\text{Fat (g/100g) fresh sample} = \frac{W * (100 - \% \text{ moisture})}{W_D}$$

Where: W weight of fat(g)

$W_2$  = weight of extraction flask after extraction (g)

$W_1$  = weight of extraction flask before extraction (g)

$W_D$  = weight of dried sample (g)

**e) Total ash determination (AOAC, 2000, 941.12)**

The porcelain dish which was used for the analysis was cleaned by drying at 120 °C and igniting at 550 °C in furnace for three hours. Then the dish was removed from the furnace and cooled in a desiccator. The mass of the dish was measured by analytical balance ( $W_1$ ). About 3g of the sample was weighed in to porcelain dish ( $W_2$ ). The sample was dried at 120 °C for one hour in drying oven (Mettler, 854 schwabach, Germany). The sample was removed from the drying oven and carbonizes by blue flame of Bunsen burner by placing the sample dish on wire gauze. The sample was then placed in furnace (Carbolite, astonlane Hope, Sheffield S302RR, England) at about 550 °C until free from carbon and the residues appear grayish white (about 8h). The sample was removed from the furnace and if the ashing was incomplete it was moistened by the few drops of water and placed in an oven at 120 °C for 1h and re-ash at 550 °C until white ash color is obtained. It was removed from the furnace and placed in the desiccator. Finally the mass was weighed ( $W_3$ ).

$$\text{Ash (\%)} = \frac{W_3 - W_1}{W_2 - W_1} \times 100\%$$

Where:  $W_1$ - Weight of the dish (g)

$W_2$ - Weight of fresh sample and dish (g)

$W_3$ -Weight of ash and dish(g)

## f) Carbohydrates

Total carbohydrate was calculated by difference with the exclusion of crude fiber.

$$C(\%) = 100 - P + F + Fi + A + W$$

Where: P – percentage of protein

F – Percentage of fat

Fi – Percentage of crude fiber

A – Percentage of ash

W – Percentage of water

### 3.3.2 Vitamin C

The vitamin C content of the juice and powder was determined using 2, - dichloroindophenol titrimetry (AOAC Method 967.21 in AOAC, 2000, cit. in Nielson, 2003)

#### **Procedure**

5 g of sample was weighed and also 0.6 g of trichloroacetic acid was measured and diluted with 100ml of water. To extract the solution each sample was mixed with trichloroacetic acid by blending and transferred in to beaker to settle .Then the solution was filtered by using filter paper in to Erlenmeyer flask. 1 g vitamin C was dissolved with 5% metaphospheric acid. Take from the 100ml and dilute with 50ml and then 1ml saturated Bromine was added in 5 test tubes which are used as standard. Then standard solution prepared and in each test tube with required amount of met phosphate.

In one blank test tube 4ml met phosphate was added. And also 1ml bromine was added to extracted samples, 10 ml Thiourea in 6 conical flask was prepared, 10 ml of filtered sample was added in each conical flask and mixed .Then 4ml was taken from each and added in to empty taste tube. 2% 1mlDNPH was added in to each prepared and metaphosphate mixed taste tube and also 2%

concentrated 1ml DNPH added to the conical flask which contains thiourea. Then all placed in water bath at 38<sup>o</sup>C about 3 hours. Then it was taken out from water bath and cooled for 5 minutes in cold water .5ml 85% concentrated sulfuric acid was added in all test tube including the blank. Then 1ml 2%2,4DNPH was added in the blank. After 30 minutes exposure of room temperature the sample was filtered .Then the spectrophotometer calibrated

**Calculation:**

$$\text{Mg of ascorbic acid/ 100g} = \frac{A_{\text{sample}} - A_{\text{blank}} \times 10}{A_{10\text{microgm std}} - A_{\text{blank}}}$$

**3.3.3 Total soluble solids**

The total soluble solids (TSS) level of the fruits puree was determined according to AOAC method by using hand refractometer, at room temperature (range from 18 to 23°C).

**3.3.4 pH value**

The pH of mango and banana fruit puree was determined by using digital pH meter (Model: Knick 646) at 25°C according to AOAC method No. 981. 12 .

**3.3.5 Viscosity**

Viscosity determined using SV-10 VIBRO Viscometer 2001 procedure. Pour the sample into the cup until its surface reaches between the level gauges. The level gauge indicates between 35 and 45ml. Attach the cup on the table along the guides. Gently lower the sensor plates above the sample surface and measure the viscosity.

**3.3.6 Solubility**

Solubility was determined according to the Eastman and Moore method (1984), with some modifications 100 ml of distilled water and 1g of powder were added by mixing at high velocity in a mixer for 5 min. The solution was placed in a tube and centrifuged at maximum speed in 5 min. An aliquot of 25 ml of the supernatant was placed in previously weighed Petri dishes and immediately oven-dried at 105 °C for 5 h. Solubility (%) was calculated by weight difference.

### **3.3.7 Bulk density & Particle size**

The bulk density of juice and the powder was determined by Narayana , N. (1984). The tare weight of the 100ml graduated cylinder was determined 66g and 64g of mango and banana puree and 10g of powder was weighed into a 100ml graduated cylinder then gently dropped 10 times onto a rubber mat from a height of 15 cm. The bulk density was calculated by dividing mass of the puree and the powder by the volume occupied in the cylinder and recorded as g·ml. The particle size was determined by using an inverted metallurgical microscope (Model PME3, Olympus Optical).

### **3.4 Sensory Analysis**

Sensory evaluation was conducted for each mango and banana powders. The evaluation was carried out by eight semi-trained panelists of whom three were female and five were male comprised of students of the Food engineering stream. Panelists were asked to give acceptance score for four attributes: color, aroma, taste and overall acceptance using the five point hedonic scale, in which 1 represent extreme dislike, 2 represent dislike, 3 represent neither like nor dislike, 4 like and 5 represent for extremely like. The powder was diluted with warm water placed in glasses and coded. The powder samples were served to each panelist in a random order.

### **3.5 Experimental Design and Data Analysis**

The experiment was conducted in a completely randomized design .Samples were analyzed in duplicates. The data were subjected to analysis of variance, and the level of significance was set at 5% using a statistical software SPSS version 17.

## CHAPTER 4

### RESULTS AND DISCUSSION

#### 4.1 Physical Properties of the Mango and Banana Puree

The laboratory results of the physical analysis of mango and banana juice are presented in Table 4.1. Accordingly the result of total soluble solids, bulk density, viscosity and pH are described below.

Table 4.1 Physical properties of the mango and Banana juice (Mean  $\pm$  SD)

Variety	Physical parameters	Values of fresh mango and banana puree	Acceptable range
Improved mango puree	Bulk density (kg/m <sup>3</sup> )	0.980 $\pm$ 0.014	-----
	Total soluble solid (°Brix)	11.000 $\pm$ 0.056	12.000-16.000
	pH	3.500 $\pm$ 0.000	3.500-4.000
	Viscosity(Pa.s)	0.540 $\pm$ 0.042	0.250
Local mango puree	Bulk density (kg/m <sup>3</sup> )	0.880 $\pm$ 0.127	
	Total soluble solid (°Brix)	10.300 $\pm$ 0.424	12.000-16.000
	pH	3.500 $\pm$ 0.000	3.500-4.000
	Viscosity(Pa-s)	0.480 $\pm$ 0.070	0.250
Banana puree	Bulk density (kg/m <sup>3</sup> )	1.020 $\pm$ 0.042	-----
	Total soluble solid (°Brix)	15.000 $\pm$ 0.989	15.000-18.000
	pH	5.000 $\pm$ 0.000	4.5000-5.000
	Viscosity(Pa.s)	1.160 $\pm$ 0.056	0.250

#### a) Viscosity of mango and banana puree

It is desirable to keep the viscosity of a material to be spray dried below 0.250 Pa.s at the dryer atomizer (Anonymous, 2003). As indicated from table 4.1 the viscosity of improved and local mango were 0.54, 0.48 pa-s respectively and the viscosity of banana powder was 1.16 pa-s. These values exceeded the recommended values of 0.25 pa.s. Thus, the puree was diluted to reduce the viscosity to 0.21 Pa-s prior to spray drying.

#### **b) Total soluble solids of juices**

The total soluble solid of mango and banana puree were determined directly from the Abbey hand refractometer. The method is especially suitable for ripe fruit juice, with significant sugar content, as the determination of TSS is based on the capacity of sugar in the juice to deviate light. Table 4.1 indicated that the concentration of soluble solids of mango improved and Local mango variety puree were 11 °Brix, and 10.3°Brix, respectively while for banana puree was 15 °Brix. The concentration of mango puree was changed by vacuum evaporation method to 55% and 50% moisture content.

#### **c) Bulk density**

Bulk density depends on the density of the solid composing the material, on air volume inside the particles (occluded and in open pores) and on the shape of the particles that influences the amount of interstitial air between the particles (Alessandro, 2009). The bulk density of improved, local mango puree and banana puree was 0.98, 0.88 and 1.02 kg/m<sup>3</sup> respectively. Bulk density of local variety mango puree was found to be lower than the improved mango juice.

#### **d) pH**

The mango puree has a pH value of (3.5). Similar to other fruit juices, mango juice contained sugars (glucose, fructose and sucrose) that would contribute to powder stickiness during spray drying. The banana juice has a pH value of 5 which is almost similar to those reported by other researchers (Cano *et al.*, 1997, Khalil,*et al.*,1989, Kojima; 1996; Krokida *et al.*, 1997).

### **4.2 Yield of Mango and Banana Juice Powder**

#### **a) Mango powder**

The result of this study showed that production of mango and banana powder was totally dependent on feed flow rate and inlet temperature. The investigation was aimed at studying the effect of the level of independent variable on the quality and quantity of the product. According to scaled up from laboratory to large scale production result one kg of mango fruit could produce about 0.230 kg of powder having 4% moisture content at inlet temperature of 200°C and flow rate of 3.6 ml/min(12% pump rate). The powder had good reconstitution property, color and flavor retention. Caking of mango powder was observed.

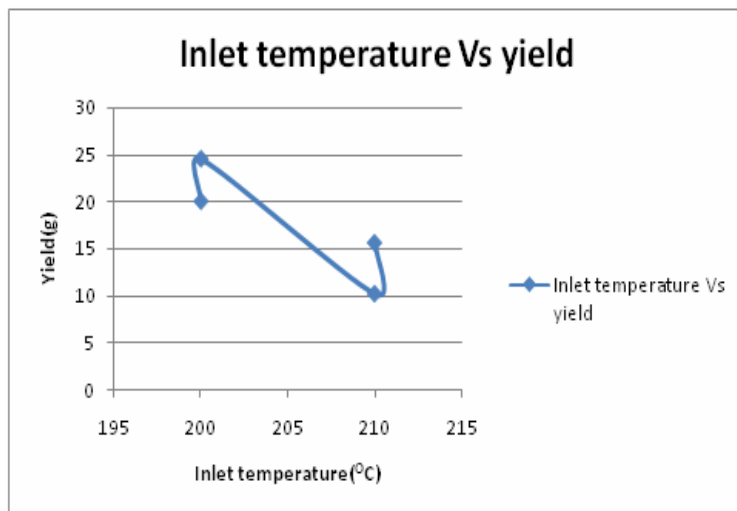


Figure 4.1 the effect of inlet temperature on yield of improved mango powder

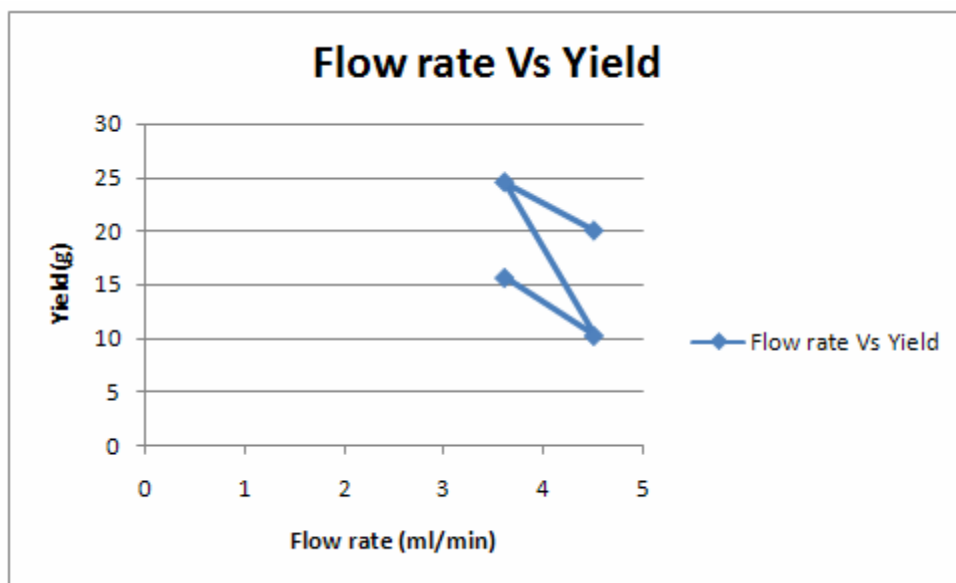


Figure 4.2 the effect of flow rate on yield of improved mango powder.

Table 4.2: Yield of powder obtained from spray dried mango juice (Mean±SD).

Type of material	Inlet temperature(°C)	Flow rate ml/min (Pump rate in %)	Yield(g)	Moisture content (%)
Improved variety mango juice powder	200	4.5(15)	20.000±0.000	4.250±0.707
	200	3.6(12)	24.500±0.707	4.000±0.001
	210	4.5(15)	10.200±0.155	4.000±0.000
	210	3.6(12)	15.600±0.282	3.800±0.000
Local variety mango juice powder	200	4.5(15)	10.350±1.070	4.000±0.000
	200	3.6(12)	10.500±0.141	3.800±0.000
	210	4.5(15)	8.500±0.212	3.800±0.000
	210	3.6(12)	9.200±0.296	3.600±0.000

The optimum operating conditions were to be found as 3.6 ml/min flow rate (12% of pump rate) and 200 °C inlet temperature. The amount of powder produced weighed 24.5g with vitamin C content of

192.24 (mg/100g). Thus, temperature and flow rate have significant effect ( $P < 0.05$ ) on mango powder yield.



Fig4.3 Mango powder at 200°C



Fig 4.4 Mango powder at 210°C

#### **b)Banana powder**

The results showed that one kg of whole banana could produce about 0.1kg of banana powder having a moisture content of 2.8 % at inlet temperature of 170 °C and 3.6 ml/min flow rate (12% of pump rate). The powder retained its color and flavor.

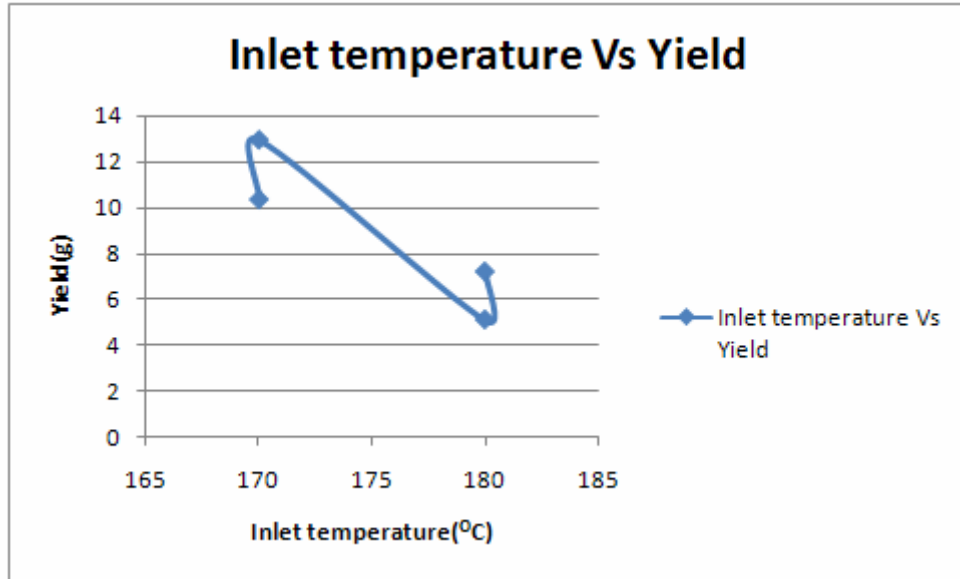


Figure 4.5 Effect of inlet temperature on yield banan powder

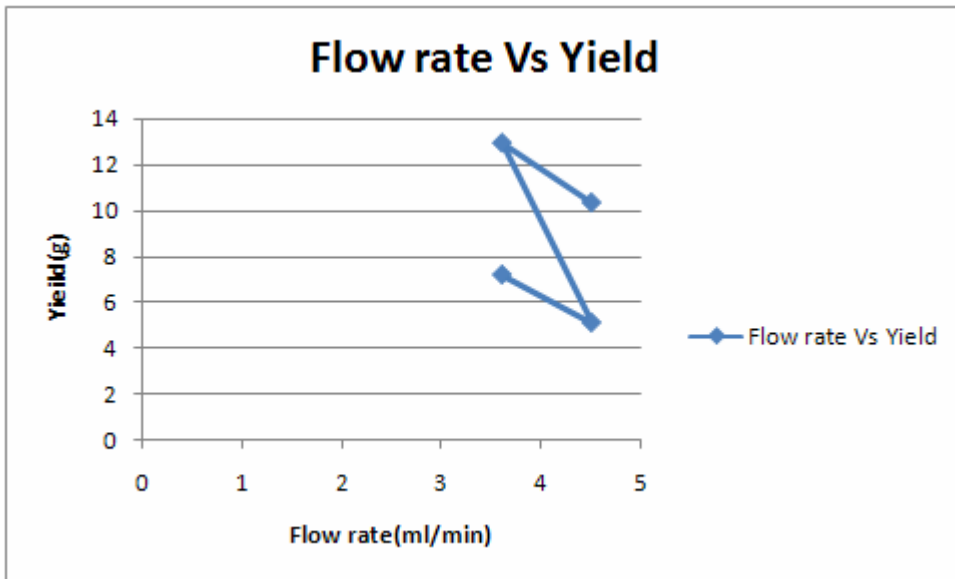


Figure 4.6 Effect of flow rate on yield banan powder

Table: 4.3 Yield of powder obtained from spray- dried banana puree (Mean±SD)

Type of material	Inlet temperature(°C)	Flow rate ml/min	Yield (g)	Moisture content(%)
------------------	-----------------------	------------------	-----------	---------------------

		(Pump rate in %)		
Banana powder	170	4.5(15)	10.350±0.721	3.500±0.000
	170	3.6(12)	12.950±0.862	3.250±0.000
	180	4.5(15)	5.100±0.212	3.000±0.000
	180	3.6(12)	7.200±0.424	2.800±0.000



Fig 4.7 Banana powder at 170°C

The optimum operating condition was found to be 3.6 ml/min flow rate (12% pump rate) and 170 °C inlet temperature .The amount of powder produced weighed 12.95g with vitamin C content of 20.97(g/100g). Thus, temperature and flow rate have significant effect ( $P<.05$ ) on banana powder yield.

### 4.3 Spray Dried Powder Characteristics

The powders that are formed as a result of spray drying are unique due to both material composition and drying conditions.

#### a)Yield

The result in Table 4.4 indicates that increasing the inlet air temperature and flow rate reduced the yield of mango and banana powder. Accordingly the maximum yield was obtained at inlet temperature of 200°C and 3.6 ml/min flow rate (12% pump rate) for mango powder and at inlet

temperature of 170°C and 3.6 ml/min flow rate (12% pump rate) for banana powder. Air temperature often caused the melting of powder and cohesion wall so the amount of powder production reduced. Thus, temperature and flow rate have significant effect ( $P < 0.05$ ) on both mango and banana powder yield.

### **b) Solubility**

The instant properties of a powder involve the ability of a powder to dissolve in water. Solubility of most powdered foods are intended for rehydration and the ideal powder would wet quickly and thoroughly, sink rather than float, and disperse/dissolve without lumps Hoge Kamp & Schubert (2003). Fruit spray drying requires knowledge of its properties and factors affecting the process. Solubility problems occur when foods are submitted to high temperatures, and especially, in products with high concentration of solids. Fruit spray drying requires knowledge of its properties and factors affecting the process.

The result shows that powdered mango and banana juice solubility are functions of inlet temperature and flow rate. The result at low temperature 200°C, and flow rate of 3.6 ml/min and 4.5 ml/min (12% & 15% pump rate) showed a high degree of solubility, reaching values above 86% and 85.5%. Whereas when the temperature was 210°C and flow rate of 3.6 ml/min (12% pump rate) and 4.5 ml/min (15% pump rate), solubility decreased to around 67.3% and 66.7 for mango powder. And in the case of banana powder at low temperature 170°C and flow rate of 3.6 ml/min (12% pump rate) and 4.5 ml/min (15% pump rate) showed a high value of solubility, reaching values above 76.24% and 75.5%. Whereas when the temperature was 180°C and flow rate of 3.6 ml/min (12% pump rate) and 4.5 ml/min (15% pump rate) solubility decreased to around 61.27% and 60.31%. Temperature and flow rate significantly ( $P < 0.05$ ) the solubility of mango and banana powder.

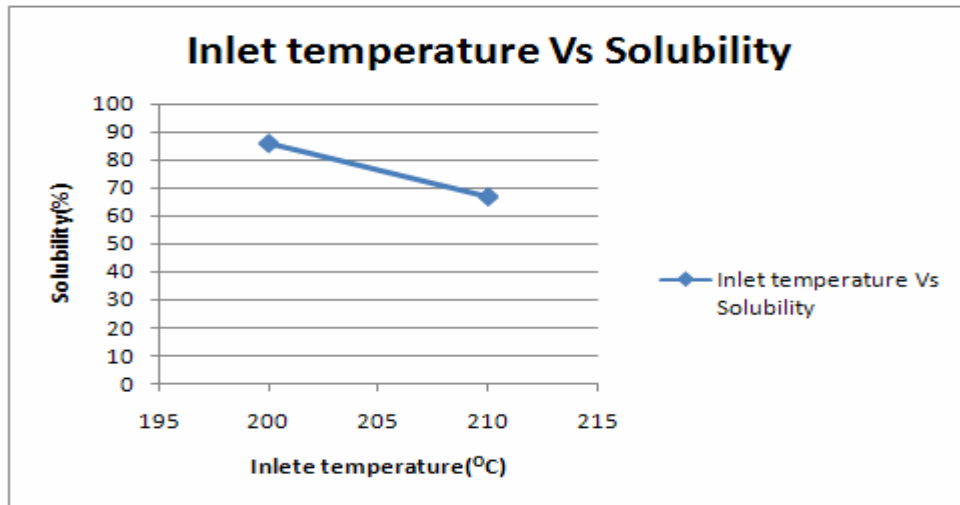


Figure 4.8 Effect of inlet temperature on solubility of improved mango powder

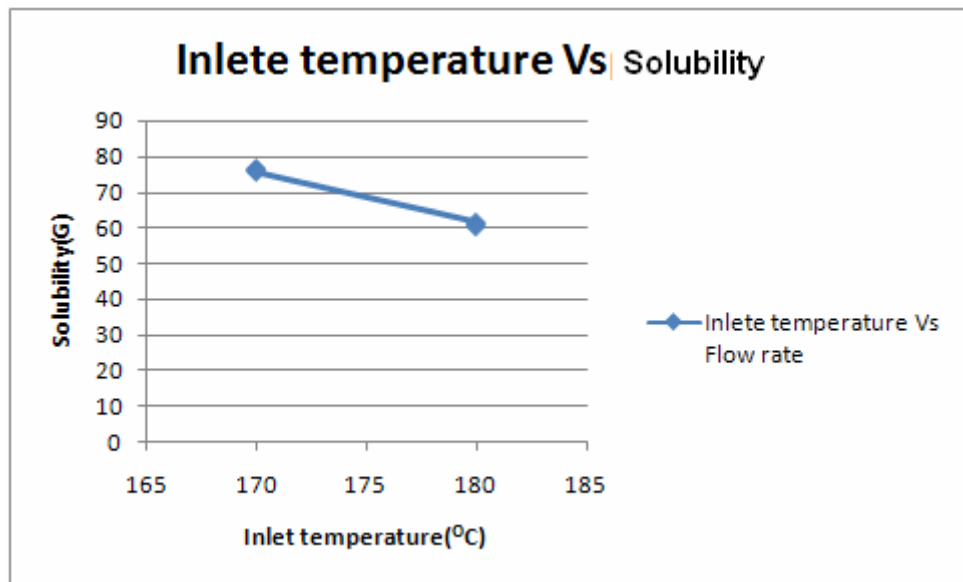


Figure 4.9 Effect of inlet temperature on solubility of banana powder.

### C) Moisture content and bulk density

All of the drying conditions reduced the moisture content of the powder to less than 5% which is desirable for spray dried powders (Table 4.5). Each independent variable had a treatment effect on moisture content of the finished powder ( $p < 0.05$ ). Higher inlet drying air temperatures often resulted in

decreased moisture content. Generally, the greater the temperature difference between the particle and the drying air, the greater the heat transfers into the particle, and thus the greater the evaporation rate. Goula et al. (2004a) reported similar results for spray dried tomato paste. Moisture content also increased with increasing flow rate.

The experimental results in Table 4.4 showed that at constant feed flow rate, increasing inlet air temperature reduces the residual moisture content (in these experimental the outlet temperature increased with increases of inlet air temperature for all cases) which also decreases the bulk density of the powder. And the feed temperature of improved and local variety of mango and banana powder at temperature of the feed has a variable effect on bulk density. If the feed is already easily atomized, increased feed temperature can lower bulk density. This variable is much dependent on the characteristics of the product (Masters, 1991). If a feed rate increase results in higher residual moisture content, the powder bulk density will also increase (Masters, 1991). Conversely, Banat et al. (2002) found that particle size could increase and bulk density decrease with increasing feed rate as a result of an increased potential for droplets to collide and coalesce. Table 4.4 showed that as inlet temperature increases the bulk density, solubility and moisture content decrease and vice versa.

It was also indicated that at constant inlet temperature and increased feed flow rate, residual moisture of the powder was increased. Increasing the feed flow rate reduces the percentage of soluble solids, because of the higher droplet moisture content and thinned dried layer on the powder particles and causes an increase bulk density. The earlier researchers also made similar conclusions (Chegini and Ghobadian, 2010).

The result showed the effect of inlet air temperature on the bulk density mango and banana powder. Accordingly at constant feed flow rate, increasing the inlet air temperature reduced the bulk density. Bulk density of mango powder at 200°C and at 210°C was 0.3502g/cm<sup>3</sup> 0.3360g/c m<sup>3</sup> respectively. Whereas, the bulk density of banana powder at 170°C and 180°C were 1.02 g/c m<sup>3</sup> and 1.00 g/c m<sup>3</sup> respectively. The experimental result confirms the above justification. Bulk density of banana and mango powders were significantly (p<0.05) affected by inlet temperature and flow rate (Table 4.4).

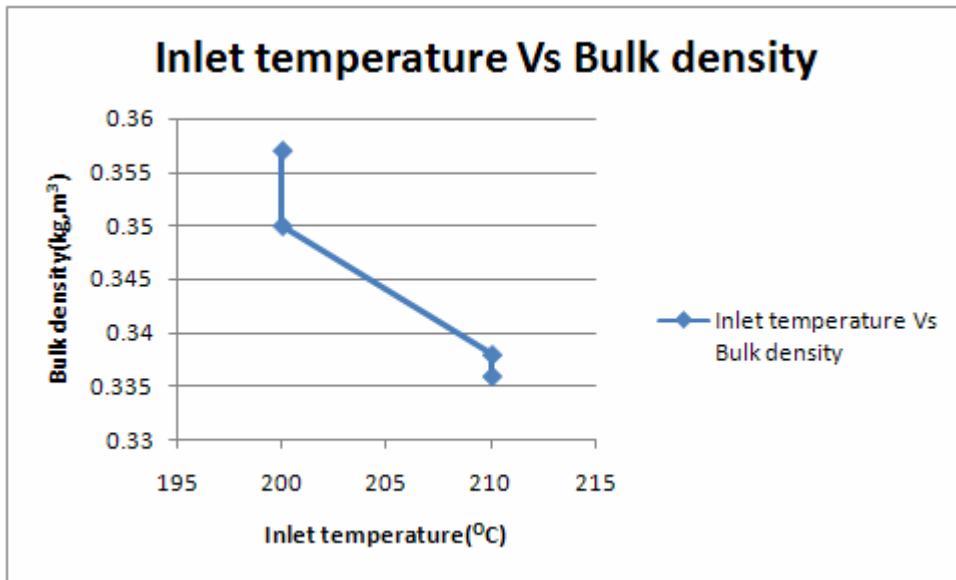


Figure 4.10 Effect of inlet temperature on bulk density of mango powder.

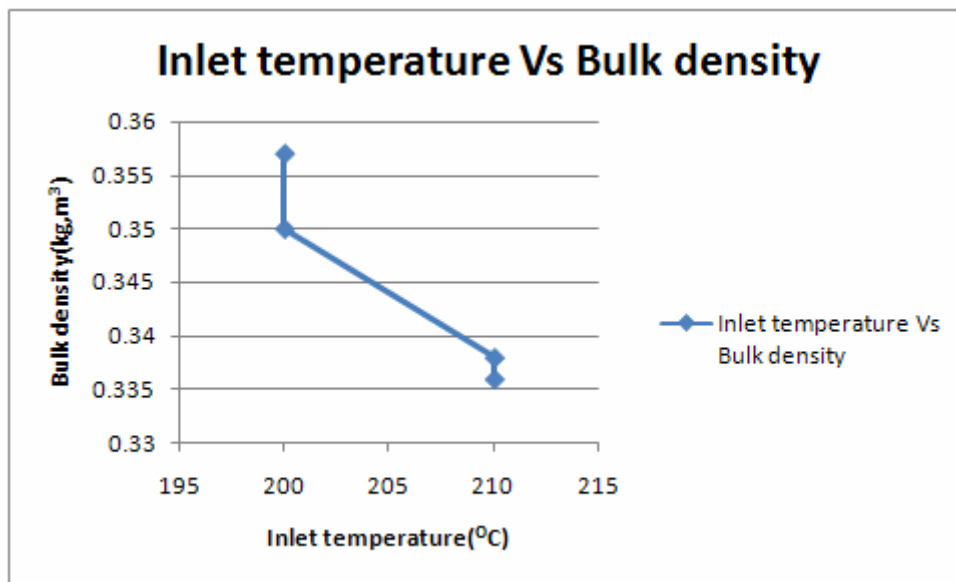


Figure 4.11 Effect of inlet temperature on bulk density of banana powder.

**e) Particle size of powder**

Goula and Adamopoulos (2004) observed that the droplet size of the material increases as feed concentration and viscosity increase and energy for atomization decreases, resulting in larger dried

particles. Table 4.5 also indicates that on increasing inlet air temperature, particle size is also increased. Increases of inlet air temperature often result in a rapid formation of dried layer at the droplet surface. This hardened skin does not allow the moisture to exit from the droplet, a consequence of which is that the particle size is increased. Powders for both fruits measure less than 150 $\mu$ m and thus are considered of a fine particle size. The experiment result indicated that the particle size of mango at 200 °C, 210 °C, and banana powder at 170 °C and 180 °C were 40.33 $\mu$ m, 42  $\mu$ m, 39  $\mu$ m, 40  $\mu$ m. These findings related with research conducted by the others.

Table: 4.4 Properties of powders (Mean $\pm$ SD)

powder types	inlet air temperature (°c)	Flow rate ml/min (Pump rate in %)	Bulk density(kg/m <sup>3</sup> )	Moisture content (%)	Solubility (%)	Particle size ( $\mu$ m)	yield (g)
Improved mango powder	200	4.5(15)	0.357 $\pm$ 0.005	4.250 $\pm$ 0.070	85.500 $\pm$ 0.770	40.332 $\pm$ 0.093	20.000 $\pm$ 0.000
	200	3.6(12)	0.350 $\pm$ 0.007	4.000 $\pm$ 0.000	86.130 $\pm$ 0.381		24.500 $\pm$ 0.707
	210	4.5(15)	0.338 $\pm$ 0.002	4.000 $\pm$ 0.000	66.700 $\pm$ 0.424	42.000 $\pm$ 1.414	10.200 $\pm$ 0.155
	210	3.6(12)	0.336 $\pm$ 0.069	3.800 $\pm$ 0.000	67.300 $\pm$ 0.707		5.600 $\pm$ 0.282
Banana powder	170	4.5(15)	1.020 $\pm$ 0.014	3.250 $\pm$ 0.027	76.240 $\pm$ 0.240	39.000 $\pm$ 2.820	12.950 $\pm$ 0.862
	170	3.6(12)	1.050 $\pm$ 0.042	3.500 $\pm$ 0.000	75.500 $\pm$ 0.424		10.350 $\pm$ 0.721
	180	4.5(15)	0.990 $\pm$ 0.014	2.800 $\pm$ 0.000	61.270 $\pm$ 1.796	40.000 $\pm$ 1.414	7.200 $\pm$ 0.424
	180	3.6(12)	1.000 $\pm$ 0.028	3.000 $\pm$ 0.000	60.310 $\pm$ 0.763		5.100 $\pm$ 0.212

#### 4.4 Proximate Analysis

Proximate analysis of improved and local mango juice powder, banana puree and powder were conducted and summary of results of moisture content, crude protein, crude fat, crude fiber, ash and total carbohydrate is presented in Tables 4.5 and 4.6. All powders were dried to an acceptable level below 5 g water/100 g.

Table 4.5 Proximate composition of mango pulp and powder (Mean±SD)

Sample	Temperature (°C)	Proximate composition (g/100g)						
		Moisture	Crude fat	Crude protein	Total ash	crude fiber	Total Carbohydrate	Vitamin C(mg/100g)
Improved variety of mango pulp	At room temperature(20 )	89.258±0.035	0.305±0.030	0.380±0.011	0.510±0.01414	6.360±0.155	9.544±0.001	33.665±0.219
		89.181±0.010	0.286±0.041	0.290±0.001	0.450±.042	5.710±0.028	9.789±0.007	54.160±0.480
Improved mango variety powder	200	4.000±0.000	2.932±0.310	2.998±0.070	2.900±0.014	0.435±0.021	76.554±0.285	192.240±0.572
	210	3.800±0.000	2.382±0.030	2.746±0.093	2.730±0.028	0.380±0.070	76.797±0.333	82.805±1.081
Local mango variety powder	200	4.000±0.000	2.131±0.011	2.441±0.024	3.985±.077	0.485±0.007	85.150±0.291	149.315±1.294
	210	3.800±0.000	2.508±0.296	2.330±0.002	2.780±0.028	0.390±0.000	86.292±.060	172.755±2.057

Table 4.6 Proximate composition of banana pulp and powder (Mean±SD)

Sample	Temperature (°C)	Proximate composition (g/100g)						
		Moisture	Crude fat	Crude protein	Total ash	Crude fiber	Total Carbohydrate	Vitamin C(mg/100g)
Banana pulp		77.486±0.135	1.027±0.153	0.758±0.041	0.800±0.014	0.220±0.028	19.927±0.044	12.160±0.608
Banana powder	170	3.250±0.027	9.188±1.057	6.321±0.027	7.400±.509	0.435±0.063	74.112±0.605	20.965±0.346
	180	2.800±0.000	8.784±0.204	6.102±0.0288	7.105±0.176	0.385±0.120	73.866±0.116	9.030±0.664

The results revealed that improved mango puree has 89.26% moisture content, 0.38% crude protein, 0.31 % crude fat, 6.36% crude fiber, 0.51% total ash 33.66mg/100g vitamin C. Whereas, local variety of mango pulp contained 89.18 % moisture content, 0.29 % crude protein, 0.28% crude fat, 5.71% crude fiber,0.45% total ash and 54.16 (mg/100g) vitamin C . These results indicated that improved mango pulp showed higher levels of moisture, crude protein, crude fat, crude fiber, total ash and lower level of vitamin C than local variety of mango pulp. These values are within comparable the range as compared with mango puree observed by Gopalan *et al.* (1980).

The results of improved mango powder showed that at inlet temperature of 200°C and 3.6 ml/min (12% of pump rate), 4% moisture content, 2.5% crude protein, 2.93% crude fat, 0.43% crude fiber, 2.89% total ash% 192( mg/100g) vitamin C were found, and at 210°C and 3.6 ml/min (12% of pump rate) ,3.8% moisture content, 2.74% crude protein, 2.38% crude fat, 0.38% crude fiber, 2.72% total ash and165.8 (mg/100g) vitamin C were obtained. The local variety of mango powder, at inlet temperature of 200°C and flow rate of 3.6 ml/min (12% of pump rate) contained 4% moisture , 3.7% crude protein, 2.13% crude fat, 0.49% crude fiber,3.70% total ash 172.75(mg/100g) vitamin C. At inlet temperature of 210°C and flow rate of 3.6 ml/min (12% of pump rate) contained 3.8% moisture content, 2.33% crude protein, 2.51% crude fat, 0.39% crude fiber, 2.78% total ash 74.41 (mg/100 g) vitamins C. From these results, it was observed that improved variety contained more nutritional value than the local variety of mango powder. The experimental results indicated that, at constant feed flow rate, increasing inlet air temperature reduces the nutritional value of powder.

Vitamin C content of the mango powder dried at different temperatures is shown in Table 4.7. A significant loss in vitamin C content at the level of 0.05 was found in the samples dried at 210°C. The vitamin C content of the powder dried at 200°C was 192.2 g/100g while at 210°C it was 82.80 mg /100g. When compared with the fresh juice (313g/100g), the loss of vitamin C at 200°C and 210°C was 39% and 73.5%, respectively. The loss in vitamin C content during drying involves oxidation and hydrolysis. The ascorbic acid is oxidized to dehydroascorbic acid, followed by hydrolysis to 2,3-diketogulonic acid and further oxidation and polymerization to form a wide range of other nutritionally inactive products (Gregory, 2008).

In the case of banana puree the results observed during the experiment were: 77.48% moisture content, 1.03% crude fat, 1.2% crude protein, 0.8% total ash, 0.22% crude fiber and 12.16 mg/100g of vitamin C. These values indicated that high moisture content, similar crude fat, crude protein, total ash and less crude fiber as compared with the results in Morton (1987). The outcome of banana powder indicates that as the inlet temperature increases the nutritional value reduces. Table 4.6 showed that at inlet temperature of 170°C and 3.6 ml/min (12% of pump rate), 3.5% moisture content, 6.32% crude protein, 9.19% crude fat, 0.435% crude fiber, 7.4 % total ash % 20.97 mg/100g vitamin C were observed. At 180°C, 3.6 ml/min (12% of pump rate), 3.2% moisture content, 6.08% crude protein, 8.64% crude fat, 0.385 % crude fiber, 7.23% total ash and 165.8% vitamin C were obtained. In this connection at inlet temperature of 170°C the banana powder contained acceptable nutrition values which were with the range of the value presented by Arogba *et al.* (1999).

#### **4.5 Drying Time and Thermal Efficiency**

##### **a) Drying time**

The calculated result for total drying time of mango juice was 2.4 s. Of which 1.12 s is of constant rate period and 1.32s is for falling rate period. Whereas the total drying time of banana juice was 2.27s. Of which is 1.05s for constant rate period and 1.22s for falling rate banana juice. At the time of droplets hot air contact, balances of temperature and vapor partial pressure were established between liquid and gas phases. Thus, heat transfer is carried out from air towards the product as a result of temperature difference whereas water transfer takes place in the opposite direction due to the vapor pressure difference (Mahmoud, 2000). Originally the use of spray-drying was advocated as a rapid method for drying compounds and usually, drying times are of the order of 2–100 s. However, in a well-designed system 15–30 s is a fair time for the passage of the sprayed particle through the drying zone (Gharsallaoui *et al.*, 2007). Although, the result obtained is within the range of 2-100s it is slightly lower than that of the 15-30s which is 2.44s for mango powder and 2.27 for banana powder. These might be due to the equipment size of the spray drier. Camilla *et al.* (2006) reported that drying time depends on product nature, air inlet temperature and other parameters like the equipment size.

**b) Thermal efficiency**

The value of thermal efficiency obtained by calculation is presented in Table 4.7.

Table 4.7- Thermal efficiency with respect to inlet temperature and outlet temperature.

Inlet temperature( <sup>o</sup> C)	Thermal efficiency(%)	Out let temperature( <sup>o</sup> C)
160	54	87
170	55	89
180	56	93
190	56	97
200	60	92
210	60	96
220	59	102

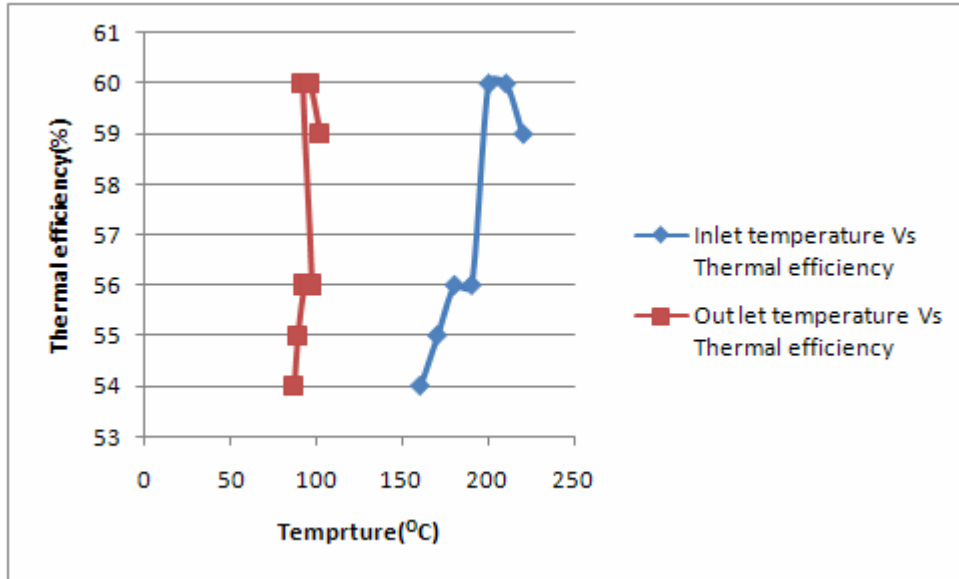


Figure 4.12 Inlet temperatures versus thermal efficiency

As indicated in the figure the efficiency of spray drier can be improved simply by increasing the inlet temperature up to 300 °C but for this case it was up to 210 °C. Due to the maximum capacity of the spray drier which is 220 °C and decreasing the outlet temperature up to 89°C. Studies revealed that the lower outlet temperature indicate that there is an increasing in moisture content of the mango powder which leads to the formation of lumping of powders (Adem *et.al*, 2007).

To dry the liquid mango pulp the inlet temperature should be 200 °C and the outlet temperature should be 96°C to obtain mango powder which has good quality (Chegini and Ghobadian,2007) which agrees with this research.

#### **4.6 Result of the Sensory Evaluation**

Sensory quality is the ultimate measure of product quality and success. Sensory analysis comprises a variety of powerful and sensitive tools to measure human responses to foods and other products. Selection of the appropriate test, test conditions, and data analysis result in reproducible, powerful, and relevant manner. Appropriate application of these tests enables specific product and consumer insights and interpretation of volatile compound analyses to flavor perception. Since temperature has effect on nutritional value, color, taste and flavor sensory evaluation was conducted on the product produced at 200 °C and 210 °C for both improved and local variety of mango powder and also at 170 and 180°C for banana powder. The color of mango powder produced at 200 °C was yellowish where as mango powder produced at 210 °C was relatively white. Mango powder developed at 200 °C had a strong mango flavor and taste. In the case of banana powder product produced at 170 °C, it was creamy to straw yellow color whereas the banana powder produced at 180 °C was relatively white in color.

According to the sensory analysis results in Table 4.8, about 75% of the panelists preferred the sample dried at inlet temperature of 200 °C and 3.6 ml/min flow rate(12% pump rate) for mango powder. In the case of banana powder about 62.5% of the panelist accepted the sample produced at inlet temperature of 170 °C and 3.6 ml/min flow rate(12% pump rate) (Table 4.9).

Table 4.8 Sensory analysis results of mango powder in terms of flavour, color and taste at selected temperature

mango variety	Inlet temperature(°C)	Each attributes	score of each attributes based on eight panelist rating				weight in percent for each attributes					
			Extremely like.	like	neither like nor dislike	dislike	extremely dislike	Extremely like.	like	neither like nor dislike	dislike	extremely dislike
Improved variety	200	color	7	1				87.5	12.5			
		flavor	6	1	1			75	12.5	12.5		
		taste	6	1	1			75	12.5	12.5		
		acceptability	6	2				75	25			
local variety	210	color	4	1	3			50	12.5	37.5		
		flavor	5	2	1			62.5	25	12.5		
		taste	5	2	1			62.5	25	12.5		
		acceptability	5	2	1			62.5	25	12.5		

Table 4.9 Sensory analysis results of banana powder in terms of flavour, color and taste at selected temperature

Inlet temperature( °C)	Each attributes	score of each attributes based on eight panelist					weight in percent for each attributes				
		Extremely like.	like	neither like nor dislike	dislike	extreme dislike	Extremely like.	like	neither like nor dislike	dislike	extreme dislike
170	color	6	1	1			75	12.5	12.5		
	flavor	5	1	1	1		62.5	12.5	12.5	12.5	
	taste	5	1	1	1		62.5	12.5	12.5	12.5	
	acceptability	5	1	1	1		62.5	12.5	12.5	12.5	
180	color	4	1	2	1		50	12.5	25	12.5	
	flavor	5	2	1			62.5	25	12.5		
	taste	5	2	1			62.5	25	12.5		
	acceptability	5	2	1			62.5	25	12.5		

## Chapter Five

# SUGGESTED PROCESS TECHNOLOGY FOR THE MANGO POWDER PRODUCTION

### 5.1 Production of Mango Powder

Spray drying process has distinct advantage over the other processes and hence it has been suggested for this project. Commercial production of one or more Fruit Juice Powder / slices / dices is possible during different period of the year. Fruit slices and dices are also produced in the same plant except manufacturing process differs slightly. The broader product range gives better capacity utilization and economic viability. These fruits will be processed and the schematic diagram of spray dried fruit juice powder / slices /dices manufacturing is summarized in following figure:

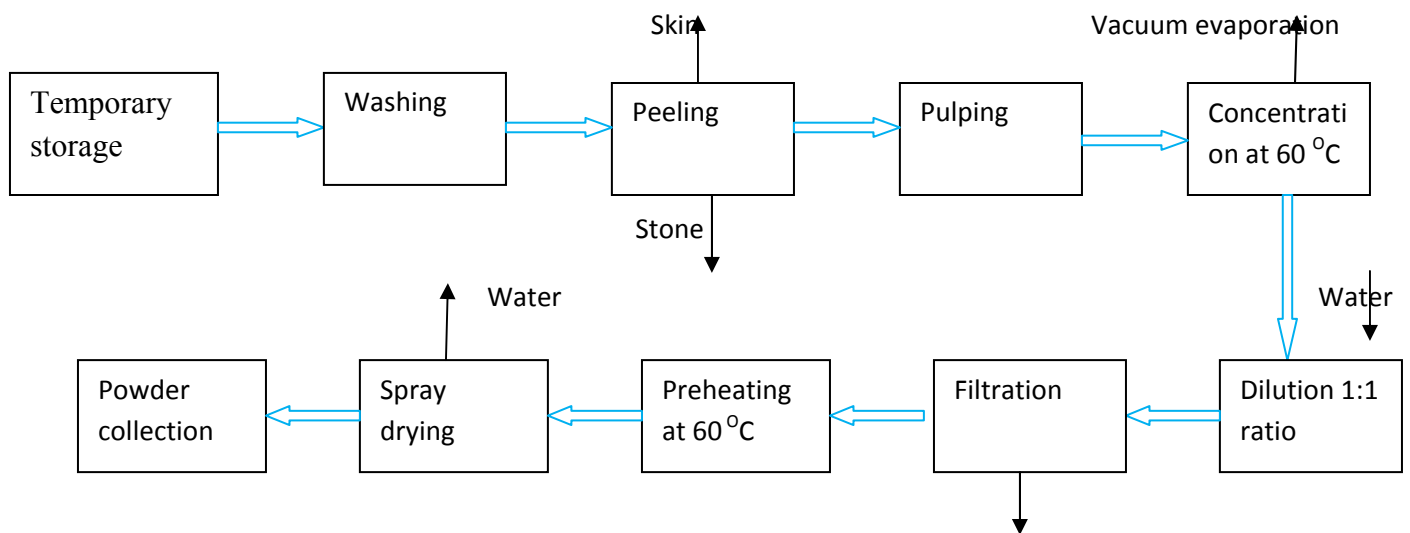


Fig5.1 Process flow sheet for mango powder production

The raw fresh and well ripened fruits are collected and stored. Fruits intended for processing have to pass a series of quality inspection. Any fruit that do not meet the required standard are removed. The mangoes are washed and disinfected. It is done to remove all kinds of dirt that survive the first one and those that come in contact with the mangoes while sorting.

The mangoes are weighed and are preparation for peeling. Peeling is achieved by applying dry caustic soda (lye peeling). After peeling the mangoes are washed in running water. This removes the last trace of peel, and caustic soda. It also removes microbe and tissue fluid, thus reducing microbial growth and enzymatic oxidation during subsequent storage.

Mango pulp or puree is prepared by homogenizing peeled ripe mango slices .Pulping enhances the surface to volume ratio, which increases the efficiency of the subsequent process, like blanching. This step must be done as quickly as possible because the sliced cut fruit rapidly becomes brown when exposed to air. The mango pulp is concentrated and filtered by vacuum evaporator and ultra membrane filtration. The fruit pulp to be atomized is preheated to around 60<sup>0</sup>C and stored in a balance tank from where; the pulp is pumped to the duplex filter, to remove suspended particles by centrifugal pump. Then the pulp is pumped to the nozzle assembly with required high pressure where the pulp has been atomized into fine droplets in the spray drying chamber. Finally the powder is collected and packed.

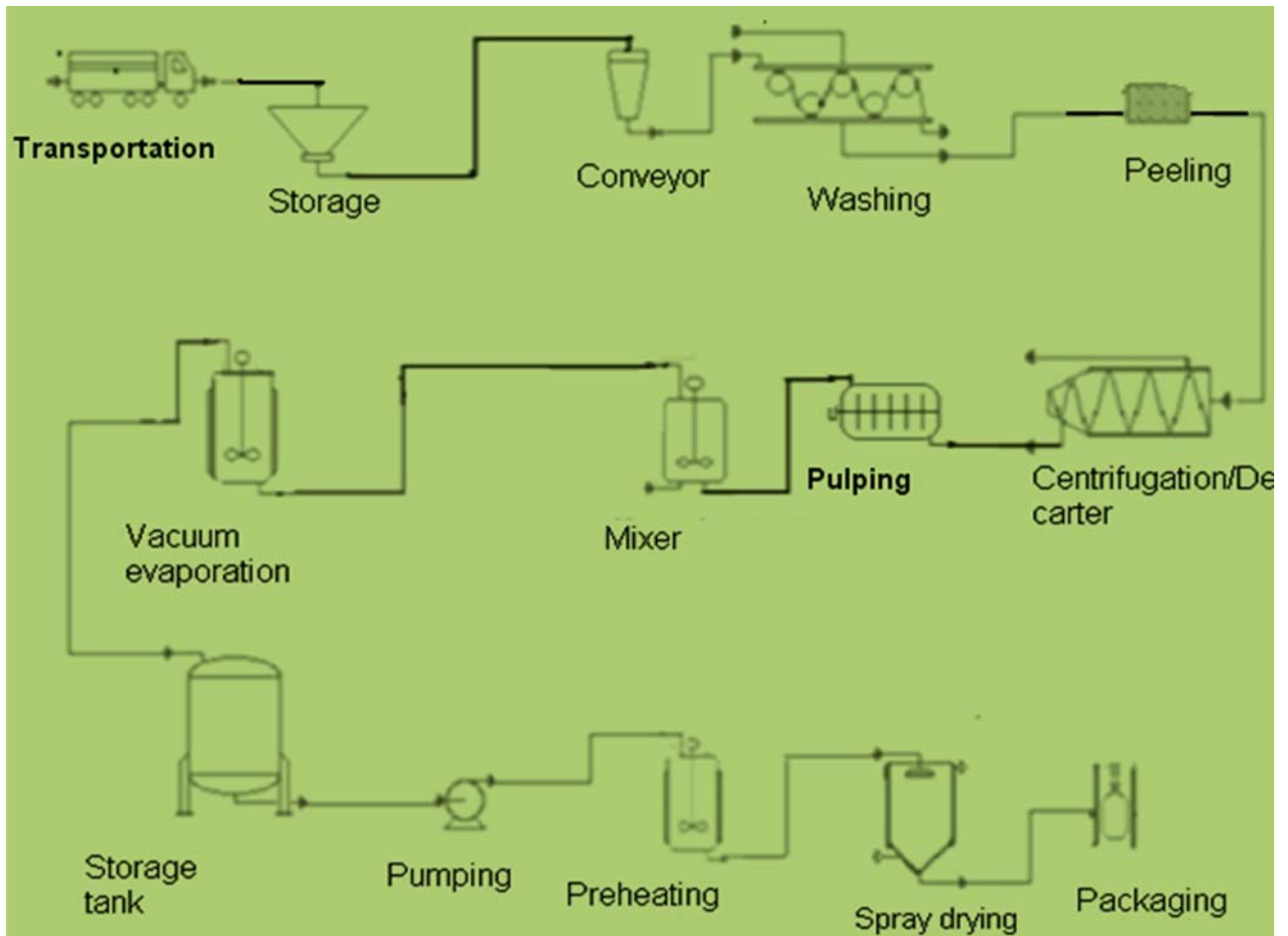


Figure 5.2 Equipment layout diagram for the production of mango powder

#### ❖ Material and Energy Balance on Major Unit Operations

There are two stages involved in planning the amount of material required to produce a given product. The first stage is to determine the amount of each ingredient needed to formulate a product. The next stage is to determine the amount of losses that are expected in commercial production. Nearly all fruit processing operation result in loss of material. This arises<sup>2</sup> from peeling, or destining, unsatisfactory fruit rejected during sorting, spillage during filling into packs, and from food stick on equipments and lost during washing. The losses greatly depend on the degree and effectiveness of the quality assurance methods used to reduce the losses.

Table 5.1 Process loss in a well managed fruit and vegetable processing plant

(Fellows, (1997) and Mani, et al (2007)

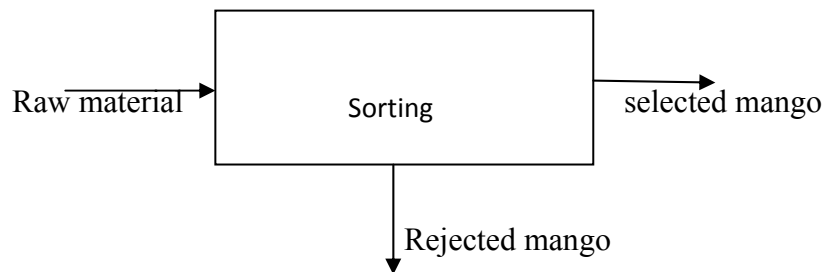
Stage in a process	Typical loss (%)
Sorting	5-50
Peeling	5-20
Washing	0.5-2
filtering	5-20
Process loss	2-5
Pasteurization	5-10
Filling and sealing	5-10

• **Material Balance**

➤ Mango fruit storage capacity

Based on yearly consumption around the world and considering Ethiopian potential of mango production 16, 000 kg/day is taken as a base to production process. The production capacity is based on projected demand and the market share that could be captured. The production commences on two shift and 300 days a year.

➤ Sorting and dipping in warm water



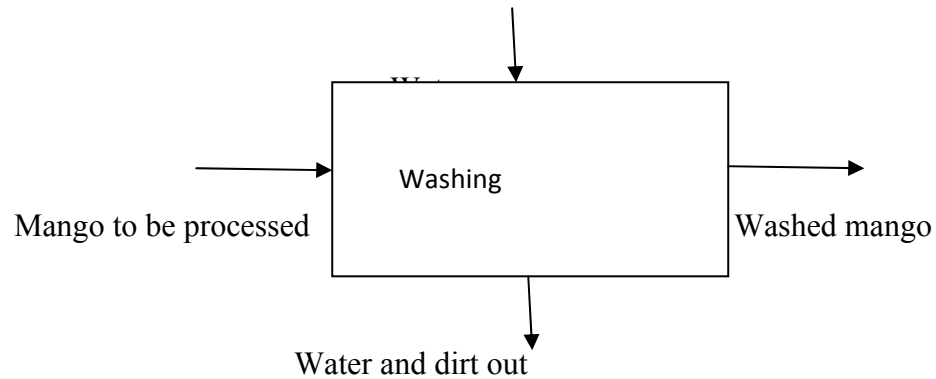
Let 5% of mango removed as waste (5% of mango rejected)

$$5/100 \times 16,000 \text{ kg} = 800 \text{ kg}$$

$$\text{Stored mango} = 16,000 - 800 \text{ kg}$$

$$= 15,200 \text{ kg}$$

➤ Washing



Let 3 liters of water used per kg for washing

$$M_{\text{water}} = 3 \text{ liter /kg} \times 15,200 \text{ kg}$$

$$= 45,600 \text{ kg/day}$$

Let only 0.5% by weight loss due to washing

$$M_{\text{waste}} = M_{\text{water}} + M_{\text{loss}}$$

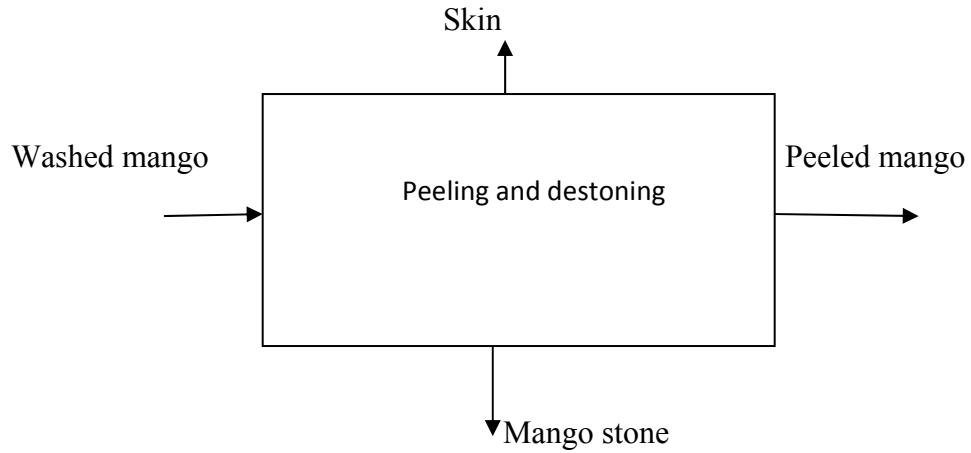
$$= 45,600 \text{ kg} + (0.005 \times 45,600) \text{ kg}$$

$$= 45,676 \text{ kg/day}$$

$$\text{Mass of washed mango} = 15,200 \text{ kg} - (0.005 \times 15,200) \text{ kg/day}$$

$$= 15,124 \text{ kg/day}$$

➤ Peeling and destoning



According to laboratory result the skin peeled was 19.2% and the stone removed 17%

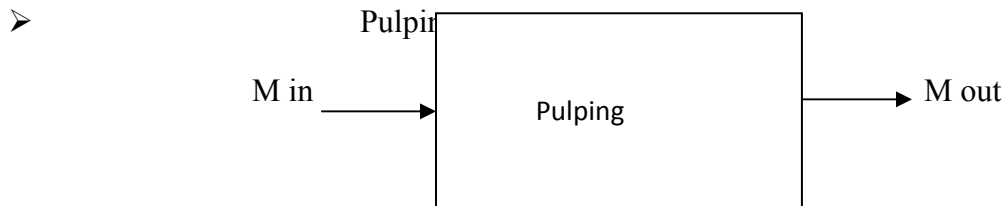
$$M_{\text{skin loosed}} = 19.28\% \times 15,124 \text{ kg/day}$$

$$= 2,915.9 \text{ kg/day}$$

$$M_{\text{stone loosed}} = 17\% \times 15,124 \text{ kg/day}$$

$$= 2,571 \text{ kg/day}$$

$$M_{\text{mango to be pulped}} = 15,124 \text{ kg/day} - (2,915.9 + 2,571) \text{ kg/day}$$



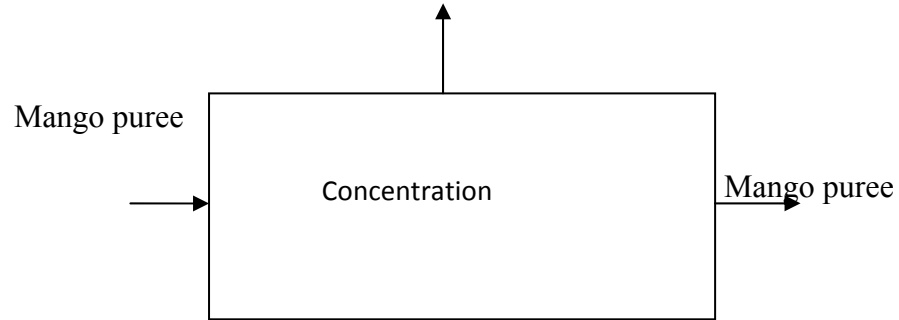
Assume that the loss is negligible

$$M_{\text{in}} = M_{\text{out}}$$

$$9637 \text{ kg/day}$$

➤ Concentration

Evaporated water



From laboratory result there was 34% of water has been evaporated by vacuum evaporation

$$M \text{ loss} = 34\% \times 9,637 \text{ kg/day}$$

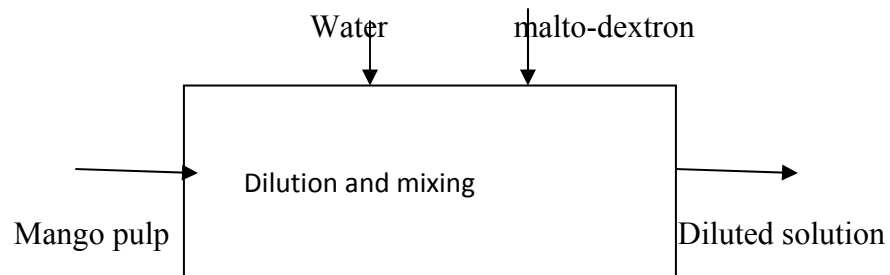
$$= 3276.58 \text{ kg/day}$$

$$M \text{ mango pulp} = 9637 \text{ kg/day} - 3276.58 \text{ kg/day}$$

$$= 6360.42 \text{ kg/day}$$

➤ Dilution and mixing

The concentrated mango pulp diluted with water by 1:1 ratio as (Bachitiar, 2007 and Mani, 2002 )



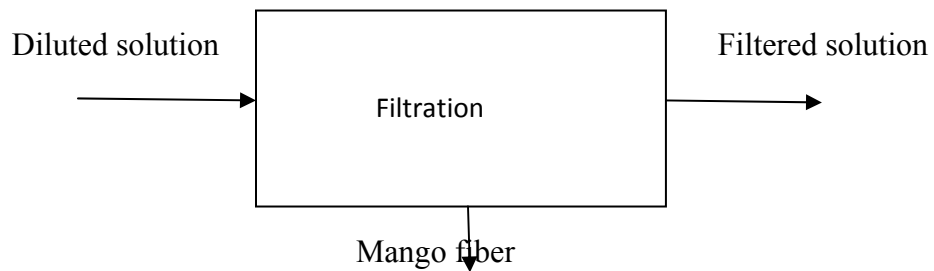
$$M \text{ solution} = M \text{ pulp} + M \text{ water} + M_{\text{mal-d}}$$

6360.42 kg/day/day of pulp + 6360.42 kg/day of water + 1199.39 kg/day of malto-dextrin (Das, 2002)

$$= 13920.23 \text{ kg/day}$$

➤ Filtration

According to the result obtained from laboratory experimental work loss due to fiber removal was 17.8% .

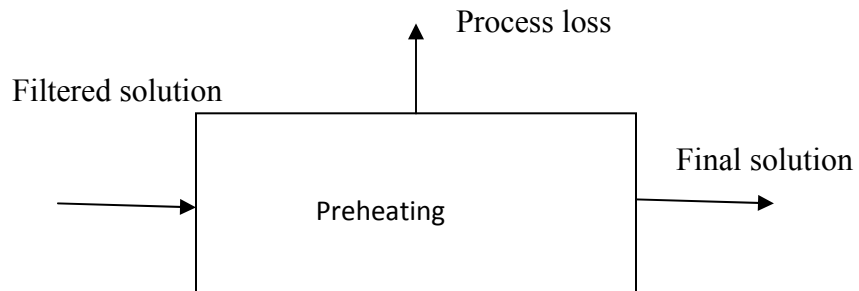


$$\begin{aligned} M \text{ fiber} &= 17.8\% \times 13920.23 \text{ kg/day} \\ &= 2,477.8 \text{ kg/day} \end{aligned}$$

$$\begin{aligned} M \text{ filtered solution} &= 13920.23 \text{ kg/day} - 2,477.8 \text{ kg/day} \\ &= 11,442.43 \text{ kg/day} \end{aligned}$$

➤ Preheating

In practical point of view there is 2% process loss



$$\begin{aligned} M \text{ process loss} &= 2\% \times 11,442.43 \text{ kg/day} \\ &= 228.85 \text{ kg/day} \end{aligned}$$

$$\begin{aligned}
 \text{M feed solution} &= 11,442.43\text{kg/day} - 228.85\text{kg/day} \\
 &= 11213.58 \text{ kg/day} \\
 &= 1,401.72 \text{ kg/hours}
 \end{aligned}$$

- **Energy Balance**

The energy balance has been made to estimate the energy required for concentration by vacuum evaporation and pre heating of the mango puree.

The heat content of incoming and outgoing materials can be calculated as follows:

$$\Sigma Q_m = M_m C_m T_m,$$

Where:

$M_m$ —the mass of the material or its components or phases processed during the given period (kg)

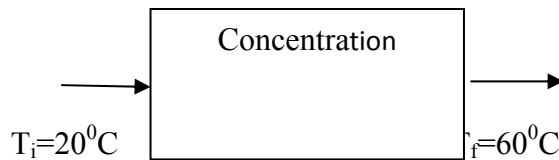
$C_m$ —specific heat of the material, or its components or phases (kJ/kg °C)

$T_m$ —temperatures of the material, or its components or phases (°C) Losses are determined empirically or by calculation.

➤ Energy balance at concentration (vacuum evaporation)

$$M_m = 6360.42 \text{ kg/day}$$

$$C_m \text{ at } 60 = 3.805 \text{ kJ/kg}^{\circ}\text{C}$$



$$\Sigma Q_m = m_m c_m T_m$$

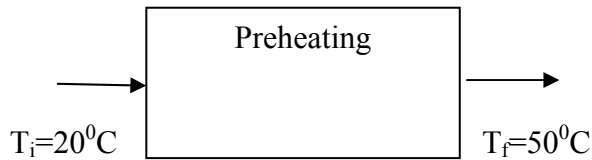
$$= 6360.42 \text{ kg/day} * 3.805 \text{ kJ/kg}^{\circ}\text{C} (60-20)^{\circ}\text{C}$$

$$= 968,055.9 \text{ kJ/day}$$

- Energy balance at preheating

$$M_m = 11213.58 \text{ kg/day}$$

$$C_m \text{ at } 50^\circ\text{C} = 3.78 \text{ kJ/kg}^\circ\text{C}$$



$$\Sigma Q_m = m_m c_m T_m$$

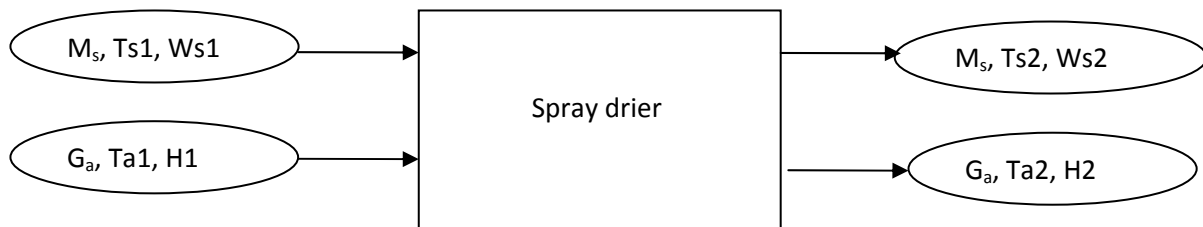
$$= 11213.58 \text{ kg/day} * 3.78 \text{ kJ/kg}^\circ\text{C} * (50 - 20)^\circ\text{C}$$

$$= 1,271,619.97 \text{ kJ/day}$$

- Atomization and spray drying

For continuous operation with negligible hold-up of the product in drying chamber, the mass input of air and feed in unit time equal to the mass output of air and product.

For calculation of air feed and product enthalpies the freezing point of water is used as reference temperature.



Where:

$M_s$  – weight units per hour of dry solid enter the spray drier in a feed

$W_{s1}$  – units of moisture per unit dry solid by weight in the feed

$W_{s2}$  - units of moisture per unit dry solid by weight in the out put

$T_{s1}$  – the feed temperature when atomized

$T_{s2}$  – the product discharge temperature

$G_a$  – the rate of supplied air per hour

$T_{a1}$  – the temperature of the inlet air

$T_{a2}$  – the temperature of the outlet air

$H_1$  – the absolute air humidity at the inlet

$H_2$  – the absolute air humidity at the outlet

❖ Known conditions

Amount of feed = 1,401.72 kg/hour

- Atmospheric air condition = 20°C and 60% RH
- $T_{a1} = 200$  °C
- $T_{a2} = 96$  °C
- Moisture content of feed = 88%
- $T_{s1} = 20$  °C
- $T_{s2} = 40$  °C

➤ **Moisture balance**

Moister entering in feed =  $M_s (W_s)_1$

Moister entering in hot air =  $G_a (H_1)$

Moister leaving the dryer in dried product =  $M_s (W_s)_2$

Moister leaving in the exhaust drying air =  $G_a(H_2)$

For no product accumulation in the chamber

$$\text{Input} = \text{Output} \text{-----} 5.1$$

$$M_s (W_s)_1 + G_a(H_1) = M_s(W_s)_2 + G_a(H_2) \text{-----} 5.2$$

$$M_s \{(W_s)_1 - (W_s)_2\} = G_a(H_2 - H_1) \text{-----} 5.3$$

➤ By similar procedure

Enthalpy or heat balance

$$\text{Enthalpy of air entering dryer} = G_a (Q_a)_1$$

$$\text{Enthalpy of feed entering dryer} = M_s(Q_s)_1$$

$$\text{Enthalpy of exhaust drying air} = G_a(Q_a)_2$$

$$\text{Enthalpy of dried solid} = M_s(Q_s)_2$$

Heat in = heat out + heat loss

$$G_a (Q_a)_1 + M_s(Q_s)_1 = G_a(Q_a)_2 + M_s(Q_s)_2 + Q_L \text{-----} 5.4$$

➤ The enthalpy of the feed and the product is given as

$$Q_s = C_{Ds} (\Delta T) + W_s C_w (\Delta T) \text{-----} 5.5$$

The enthalpy of the drying medium  $Q_a$  expressed in terms of humid air, absolute humidity and latent heat of evaporation of water at freezing point

$$Q_a = C_s (\Delta T) + H\lambda$$

$$\lambda = 597.3 \text{ kcal/kg at } 0^\circ\text{C}$$

$$M_s = 1,401.7 \text{ kg/hour} * 100/96 * 55/100 = 803.1 \text{ kg/h}$$

$$W_{s1} = 1.22 \text{ kg/kg dry solid}$$

$$W_{s2} = 4/96 = 0.042 \text{ kg/kg dry solid}$$

$$C_{Ds} = 0.4 \text{ kcal/kg. } ^\circ\text{C}$$

Where  $C_{Ds}$  – heat capacity of dry solids

$H_1 = 0.00885 \text{ kg/kg dry air (from psychometric chart)}$

$$(Q_a)_1 = C_s (\Delta T) + H \lambda, \quad \lambda = 597.3 \text{ kcal/kg}$$

$$C_s = (0.24 + 0.46 H)$$

$$\Delta T = T - T_{\text{ref}}, \text{ where } T_{\text{ref}} = 0^\circ\text{C}$$

➤ Enthalpy of inlet air

$$Q_{a1} = (0.24 + 0.46 H_1) T_{a1} + 597 H_1$$

$$= (0.24 + 0.46 * 0.00885) * 200 + 597 * 0.00885$$

$$= 54.1 \text{ kcal/kg}$$

➤ Enthalpy of outlet air

$$Q_{a2} = (0.24 + 0.46 H_2) T_{a2} + 597 H_2$$

$$= (0.24 + 0.46 H_2) * 96 + 597 H_2$$

$$= (23.04 + 44.16 H_2) \text{ kcal/kg} + 597 H_2$$

$$= (23.04 + 641.16 H_2) \text{ kcal/kg}$$

➤ Enthalpy of feed entering dryer(5.5)

$$Q_{s1} = 0.4 \text{ kcal/kg} \cdot ^\circ\text{C} * (20) + 8 * 1 * 20 = 168 \text{ kcal/kg}$$

$$Q_{s2} = 0.4 \text{ kcal/kg} \cdot ^\circ\text{C} * (40) + 0.042 * 1 * 40 = 17.68 \text{ kcal/kg}$$

➤ Moisture balance

Basis:

Dry solids dried per hour =  $803 \text{ kg/hr} * 0.96 = 770.88 \text{ kg/hr}$

Moisture entering in feed =  $770.88 * 1.22 = 940 \text{ kg/h}$

Moisture leaving in product =  $770.88 \text{ kg/h} * 0.042 = 32.38 \text{ kg/h}$

Moisture evaporated =  $770.88 \text{ kg/h} (1.22 - 0.042) = 908.1 \text{ kg/h}$

From equation 5.3

$$M_s [W_{s1} - W_{s2}] = G_a (H_2 - H_1)$$

$$G_a (H_2 - 0.00885) = 908.1 \text{ kg/h} \dots \dots \dots (1)$$

➤ Enthalpy balance

Enthalpy entering drier =  $54.1 \text{ kcal/kg} G_a + 770.88 (168 \text{ kcal/kg})$

Enthalpy leaving drier =  $G_a (23.04 + 641.16 H_2) \text{ kcal/kg} + 770.88 (17.68) \text{ kcal/kg} + Q_{\text{loss}}$ ,

Where  $Q_{\text{loss}} = 0 \dots \dots \dots (2)$

From equation 5.4

$$54.1 \text{ kcal/kg} G_a + 770.88 (168 \text{ kcal/kg}) = G_a (23.04 + 641.16 H_2) \text{ kcal/kg} + 13,629.2 \text{ kcal/kg}$$

$$54.1 G_a \text{ kcal/kg} + 129,507.84 \text{ kcal/kg} = (23.04 G_a + 641.16 G_a H_2) \text{ kcal/kg} + 13,629.2 \text{ kcal/hr}$$

Equating 1 and 2 (solving simultaneously)

$$G_a (H_2 - 0.00885) = 908.1 \text{ kg/h}$$

$$54.1 G_a \text{ kcal/kg} + 129,507.84 \text{ kcal/kg} = (23.04 G_a + 641.16 G_a H_2) \text{ kcal/kg} + 13,629.2 \text{ kcal/hr}$$

$$31.06G_a - 641.16G_{H_2} = -115,878.64$$

$$641.16G_{H_2} - 31.06G_a = 115,878.64 \text{ -----A}$$

$$G_a - 0.00885G_{H_2} = 908.1 \text{ -----B}$$

$$641.16G_{H_2} - 31.06G_a = 115,878.64$$

$$-641.16G_{H_2} + 5.67G_a = -582,237.396$$

$$-25.39G_a = -467,000$$

$$G_a = 18,458.5 \text{ kg/hr}$$

From the above equation

$$H_2 = 0.0580$$

## ❖ Equipment Selection and Sizing

### ➤ Spray dryer sizing

The sizing of spray dryers on a purely thermal basis is a comparatively simple matter since the evaporation is entirely a function of the  $\Delta t$  across the dryer.

$$G_a = m_a = 18,458.5 \text{ kg/hr} = 5.13 \text{ kg/s}$$

$$\text{Gas (air) velocity} = 0.6 \text{ m/s}$$

$$\text{Density at } 200^\circ\text{C} = 0.746 \text{ kg/m}^3$$

$$m_a = (\text{density of air}) * v_a * A_a$$

Where,  $m_a$  = mass flow rate of air

$v_a$  = the average flow velocity of the air

$A_a$  = the air cross-sectional area in the drier

$$A_a = m_a / (\text{density of air}) * v_a = 5.13 / (0.746 * 0.6) \\ = 11.46 \text{m}^2$$

But,  $A_a = \pi * D^2 / 4$

$$D = \sqrt{(4 A_a) / \pi} = \sqrt{(4 * 11.46 / \pi)} \\ = 3.8, \text{ which is approximately } 4\text{m}.$$

And using the L/D ratio of 5

$$L = 5 * D = 5 * 4 = 20\text{m}.$$

➤ **Inspection, washing, extraction unit**

complete line with tilting machine for cases; washing device; elevator; crusher/destonner machine; screw conveyor for wastes; pumps; mixing tank; pump; press (membrane type); fittings; electric board. All parts in contact with product made in stainless steel.

➤ **Peeler**

For mango peeling using mechanical means will be very time consuming. The most common methods for mango peeling is lye peeling. In conventional lye peeling the fruits are placed in a hot solution hydroxide for a specific time. The loosed skin is removed by jets of water. These

processes generates huge amount of liquid waste, being responsible for, 10% of the total waste water flow and 40% of the total biological oxygen demand in fruit processing plants. To reduce this waste load, dry lye peeling has been chosen.

➤ **De-stoning/Fruit pulping machine**

Mango de-stoner is a machine to separate mango flesh from the stone. All of the parts including the support frames are manufactured from 304 stainless steel. It has got a feeding hopper, pulp collecting hopper and removable closing case.

Has a capacity 200kg of mangoes per hour

Works in electrical power and its power consumption is 5.5kW. It is 5 meter long

➤ **Mixing tank**

For adding/dosing additives, Equipped with loading and discharging taps, washing ball, discharging throttle valve, stirrer, supporting legs. Has a capacity of 200 liters

➤ **Evaporator**

In the concentration of many fruit juices and other heat sensitive materials, single pass evaporators are preferred, because the product quality is not damaged appreciably by the short time exposure to heat. Single pass evaporators include the tubular rising film, falling film, combination of these and the plate and centrifugal types. If the solution contains dissolved solids, the resulting strong liquor may become saturated. Evaporation has three main uses in the food industry. Single effect evaporators are used when the throughput is low, a cheap supply of steam is available and a material of construction is very expensive. It is made up of three functional sections: the heat exchanger, the evaporating section, where the liquid boils and evaporates, and the separator in which the vapor leaves the liquid and passes off to the condenser.

The falling film evaporators are the most widely used in the food industry. It is almost identical to a rising film evaporator except that fluid is pumped over the top of the tube bundle. Generally, it is made of long tubes (4-8 meters in length) which are surrounded by steam jackets. This evaporator is the most popular type because it can handle more viscous fluids than the rising film evaporator and can be operated at lower temperature differentials. The residence time is 20-30 s as opposed to 3-4 min. in the rising film type.

➤ **Agitated thin film evaporators**

A thin layer of a solution is spread on the heating surface by mechanical means. It employs a heating surface consisting of one large diameter tube that may be either horizontal or vertical. The expensive construction limits application to the most difficult materials. High agitation and power intensity permits handling of extremely viscous materials. Residence times of only a few seconds permit concentration of high heat sensitive materials at high temperature differences. Economic and process considerations usually dictate that agitated thin film evaporators can be operated in single effect mode and very high temperature differences can be used.

➤ **Criteria for selection of evaporators**

The selection of suitable evaporator type for a particular application will depend on the following factors:-

- ✓ The throughput required.
- ✓ The viscosity of the feed and the increase in viscosity during evaporation
- ✓ The nature of the product required; solid, slurry, concentrated solution
- ✓ The heat sensitivity of the product
- ✓ The materials are fouling or non-fouling

➤ **Conveyors**

There are three main types of conveyors they are vibrating conveyor, Belt conveyor and Chain conveyor. Belt conveyor device is almost universal in application. It can travel for miles at speed up to 304 meter/min and handle up to 5000 tons/hr. It can also operate over short distances at speeds low enough for manual picking, with a capacity of only a few masses per hour. Belt conveyors are

inexpensive and require minimal maintenance, though they may require belt brushes and skirting to avoid major. For this project 0.508 meter or less width is required for 100Kg/h or 83Kg/h

❖ **Economic analysis of mango powder production.**

• **Total Capital Investment**

Building, equipment and manpower requirements

The factorial method of cost estimation

Capital cost estimations for process plants are often based on an estimate of the purchase cost of the major equipment items required for the process, the other cost is being estimated as factors of the equipment cost. The accuracy of this type of estimate will depend on what stage the design has reached at the time the estimate is made, and on the reliability of the data available on equipment costs.

• **Fixed and working capital**

Capital cost estimate are often based on estimate of purchase cost of the major equipment item required for the process; the other costs are being estimated as factors of the equipment cost (factorial method)

◆ **Plant parameters**

❖ Capacity, tons per year of mango powder	3,854.4
❖ Number of shifts /day	2
❖ Working days/year	300

◆ **Machinery and equipment**

If the cost of a piece of equipment or plant of size or capacity  $q_1$  is  $C_1$ , then the cost of a similar piece of equipment or plant of size or capacity  $q_2$  can be calculated from  $C_2 = C_1(q_2/q_1)^n$

Where: the value of the exponent  $n$  depends on the type of equipment or plant

The amount of total product per year = 3854.4 tone /yr

Table 5.2 Total plant and machinery cost

SN	Item	Quantity	Unit price (birr)	Total price (birr)
1	Spray dryer	1	2,522,799.9	1,522,799.9
	Cleaning (Washing) machine	1	51,169.8	51,169.8
2	Fruit conveyer	1	12,033	12,033
4	Peeler(Lye peeling machine)	2	39,663.24	79326.48
5	Pulper (de-stoning machine)	2	53,205.3	106,410.6
6	Mixer	1	60,606.76	60,606.76
7	Vacuum evaporator	1	80,000	80,000
8	Heater(Boiler)	1	51,220,849	51,220
10	Water tank (15000 liter)	3	10,280	30,840
11	Water tank (3000 liter)	1	6,098.00	6,098.00
12	Fruit powder packaging machine	1	90,000	90,000
13	Contingencies on Equipment	15%		313,575.7

	Total			3,404,080.22
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Total purchase cost of equipment will be sum of all equipment

$$PCE = 3,404,080.22$$

Direct and indirect costs that are incurred has been calculated as a function of purchased equipment cost using Lang factors for fluid solid process type given coulson vol.6

➤ **Major equipment total purchase cost**

- **Direct cost**

PCE	0.45
f1 equipment erection	0.45
f2 piping	0.45
f3 instrumentation	0.15
f4 electrical	0.10
f5 buildings, process	0.10

f6 utilities	0.45
f7 storages	0.20
f8 site development	0.05
f9 ancillary buildings	0.20

➤ **Total physical plant cost (PPC)**

$$PPC = PCE * ( 1 + f1 + f2 + \dots + f9 )$$

$$= 3,404,080.22 * 3.6 = 12,254,688.79 \text{ Birr}$$

**Indirect cost**

f10 design and eng'g	0.25
f11 contractor's fee	0.05
f12 contingency	0.10

$$\text{Fixed capital} = PPC * 1.40$$

$$= 12,254,688.79 \text{ Birr} * 1.40 = 17,156,564.31$$

$$\text{Working capital} = 5\% \text{ of fixed capital}$$

$$= 0.05 * 17,156,564.31$$

$$= 857,828.22 \text{ Birr}$$

- Total investment cost = working capital + fixed capital

$$=17,156,564.31+857,828.22 \text{ Birr}$$

$$= 18,014,392.53 \text{ Birr}$$

### ❖ **Operating (production) Costs**

As estimate of the operating costs, the cost of producing the product is needed to judge the viability of a project, and to make choices between possible alternative processing schemes. These costs can be estimated from the flow sheet, which gives the raw material and service requirements, and the capital cost estimate.

The cost of producing a product will include the items listed below. They are divided in to two groups.

1. Fixed operating costs: costs that do not vary with production rate. These are the bills that have to be paid whatever the quantity produced.
2. Variable operating costs: costs that are dependent on the amount of product produced.

#### ➤ **Fixed costs**

1. maintenance (labor and material)
2. operating labor
3. laboratory costs
4. supervision
5. plant overheads
6. capital charges
7. rates (and other local taxes)
8. insurance
9. license fees and royalty payments

➤ **Variable costs**

1. raw materials
2. miscellaneous operating materials
3. utilities (services)
4. shipping and packaging

➤ **Operating cost Variable costs**

1. Raw material cost

- Raw material required per year = 4,800 ton/year of mango fruit

$$= 4,800,000 \text{ kg/year}$$

$$\text{Price of mango fruit} = 10 \text{ Birr/kg}$$

$$\text{Cost of mango fruit} = 10 \text{ Birr/kg} * 4,800,000 \text{ kg/year}$$

$$= 48,000,000$$

$$359.86 \text{ ton/year of malto-dextrine}$$

$$\text{Price of malto- dextrine} = 15 \text{ Birr/kg}$$

$$\text{Cost of malto- dextrin} = 20 \text{ Birr/kg} * 359,860 \text{ kg}$$

$$= 7,197,200 \text{ Birr}$$

$$\text{Total raw material cost} = 48,597,855 \text{ Birr}$$

2. Miscellaneous materials 5% of maintenance = 5% \* 857,828.22 Birr/yr  
= 42,891.4 Birr/yr

3. Utilities = 937,692.5 Birr/year

Utility costs

Equipment kerosene (kg/h)

Spray dryer = 76.26

Steam: 297.78kg/h of steam is needed for concentration

$$297.78\text{kg/h} \times 8\text{hrs} \times 300\text{days/y}$$

$$= 714,672\text{kg/yr}$$

$$1000\text{kg} = \$4.5 = 59 \text{ Birr}$$

$$= 714809.6 \text{ Birr/yr}$$

Water:

$$576,000 \text{ l/yr}$$

$$0.005\text{birr/l}$$

$$\text{Total price} = 0.005\text{Birr} \times 576,000$$

$$= 2880\text{birr/yr}$$

$$\text{Total utility cost} = 981,451.74 \text{ Birr/year}$$

4. Shipping and packaging usually neglected

$$\text{Subtotal A} = 57,116,344.24 \text{ Birr/year}$$

➤ **Fixed costs**

5. Maintenance (2-10% of FCI) 5% of fixed capital = 857,828.22birr/yr

6. Operating labor = 3,198,648 birr/year

Table 5.3 Average working labor in an industry

Average working labor in an industry		
Name of unit / department	Task, function / responsibility	Number of man power
Manager	Overall management	1
Technique and production staff	Production Technical service	40
Commercial department	Sales Purchase Property administration	30
Finance department	General accountant Cost and budget	18
Administration department	Training Human resource management	20
MIS service	Management service and planning	2
Quality control and associated services	Quality assurance	6
Audit service	Internal audit	2
Total		119

Table5.4 Average salaries on each department

Average salary on each department		
$S_{avg}$	Number of workers	Total = ( $S_{avg}$ * number of workers)
6000	1	6000
3500	40	140000
1800	30	54000
1300	18	23400
900	20	18000
3500	2	7000
1859	6	11,154
35000	2	7000
Total		266,554 Birr/month

Operating labor cost will be:

$$= 12 \text{ month/year} * 266,554 \text{ Birr/month} = 3,198,648 \text{ Birr/year}$$

7. Laboratory costs 15% of lab our cost = 479,797.2

8. Supervision 15% of lab our cost = 479,797.2

9. Plant overheads	50% of labour cost = 1,599,324
10. Capital charges	15% of the FC = 2,573,484.65
11. Insurance	1% of the FC = 171,565.64
12. Local taxes	2% of the FC = 343,131.29
13. Royalties	5% of the FC = 857,828.22
	Sub total B = 10, 252604.42Birr

Direct production costs A + B= 67368,949.05 Birr

14. Sales expense, general overheads and R & D 25% of the direct production cost  
= 16,842,237.26 Birr

Subtotal C =14,689,950.70birr

Annual production cost = A + B + C = 84,211,186.31

#### ❖ Profitability Measurements

Production cost birr/kg = annual production cost/annual production rate

$$= (84, 211, 186.31 ) / 3,854,400 \text{ kg/year}$$

$$= 21.84 \text{ Birr/kg of mango powder}$$

Production capacity = 3,854,400 kg/year

Sales income =3,854,400 kg/year \* 26.22 Birr/kg

$$= 101, 062,368 \text{ Birr/year}$$

Gross earning cost, depends on amounts of gross earning cost for entire company and income tax regulation.

Gross earning cost = total income-total product cost

$$= 101,062,368 \text{ Bir/year} - 84,211,186.31 \text{ Birr /kg of mango powder.}$$

$$= 16851181.69 \text{ Birr/year}$$

Production cost birr/kg = annual production cost/annual production rate

$$= (84,211,186.31) / 3,854,400 \text{ kg/year}$$

$$= 21.84 \text{ birr/kg of mango powder}$$

Depreciation (AAD) = 10% of FCI

$$= 10\% \times 17,156,564.31$$

$$= 1,715,656.4 \text{ Birr}$$

Let the tax rate be 35% (income tax of Ethiopia)

*Net annual earning* = Gross earning – Income tax

$$= 26,218,864.45 \text{ Birr/year} (1 - 0.35) \text{ Birr}$$

$$= 10,953,268.3 \text{ Birr}$$

NAAP = Gross earning - Tax

$$= 16851181.69 \text{ Birr/year} - 10,953,268.3 \text{ Birr}$$

$$= 5,897,913$$

**Rate of return**

$$ROI = \frac{\text{net profit}}{\text{total capital investment}} \times 100 = \frac{5,897,913}{18,014,392.53} \times 100 = 32.7 \%$$

### **Payback time**

Payback time is defined as the period required recovering the original investment outlay through the accumulated net cash flows earned by the project.

$$\text{payback period} = \frac{FCI}{NP + Depre} = \frac{17,156,564.31}{5,897,913 + 1,715,656.4} = 2.3 \text{ years}$$

#### **5.4.4 Break-even analysis**

The break-even analysis is to determine the point at which sales revenues equal the costs of products sold. When sales are below this point, the plant is making a loss, and at the point where revenues equal costs, the plant is breaking even. The break-even production is the number of units necessary to produce and sell in order fully to cover the annual fixed costs. Breakeven point is recommended to be about 60 to 70 percent. It can be computed as:

Total product cost = Total income

To calculate the total product cost and total income, unit product cost of 21.84 birr/kg of mango powder, product selling price of 26.22 birr/kg, were considered. The break-even point was calculated as:

$$(\text{Fixed charges} + \text{General expenses} + \text{Plant overhead costs}) + 21.84n = 26.22n$$

$$2,526,335.59 + 3,368,447.45 \text{ birr} + 4,210,559.32 + 21.84n = 26.22n$$

Where n is the number of kg of product produced.

$$4.38n = 10105,342.36 \text{ kg}$$

$$n = 2,307,155.79 \text{ kg}$$

This is the break-even capacity of production. This value is 60% of the plant capacity. Based on the preliminary economic evaluation, the suggested project has a return on investment (ROI) of 32.7 % and payback period of 2.3 years. The break-even production capacity is at 60%, showing that there is good profit margin. Thus, the suggested project is financially feasible.

## **CHAPTER SIX**

### **CONCLUSION AND RECOMMENDATION**

#### **6.1 Conclusion**

Now days in Ethiopia many agro- processing industries are emerging in an alarming rate due to the current opportunity. These industries are initiating the private sector to involve in the area of fruit processing. A study aimed at development of mango and banana powder. The results showed that all of the operating parameters affected the powder physicochemical properties significantly. The investigation indicated that increasing the inlet air temperature and flow rate reduced the yield of mango and banana powder .In general inlet temperature and flow rate had enormous and significant effect on all product quality attributes .The best conditions to produce lower moisture content and higher yield mango and banana powder were inlet air temperature of 200 °C, 170°C and feed flow rate of 3.6 ml/min(12% pump rate) respectively. Under optimum conditions the desired mango powder were obtained. As a conclusion, spray drying of mango and banana fruits using spray dryer is capable of producing powder that retains its nutritional values, colour, aroma and is suitable for commercialization.

This study clearly indicated that there is a possibility of mango powder production in the country. The suggested spray dried mango powder production technology is both technically and financially

feasible. The feasibility depends on further exploration of accurate data. Encouraging result of payback period and rate of return were found. The profitability measurements revealed that the project has a return on investment of 32.7 %, payback time of 2.3 years. The technology definitely assists Ethiopia in reducing foreign exchange and creating job opportunities to the people, and results in effective resource utilization.

## 6.2 Recommendation

Further studies are recommended on:

- Banana powder production by using different drying technology by reducing stickiness problem.
- Converting tropical fruits, especially mango and banana in to different value added food products.

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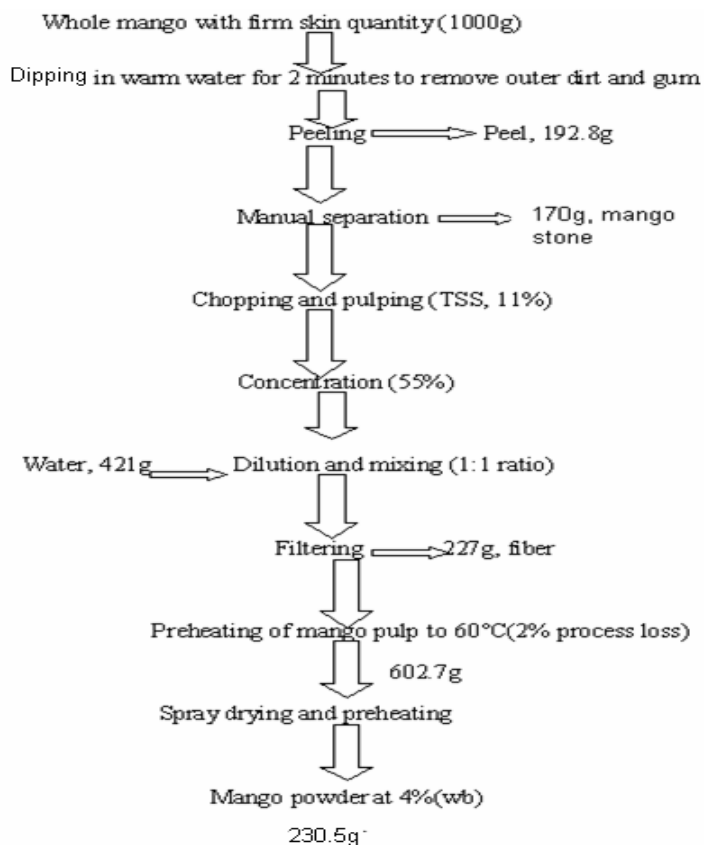
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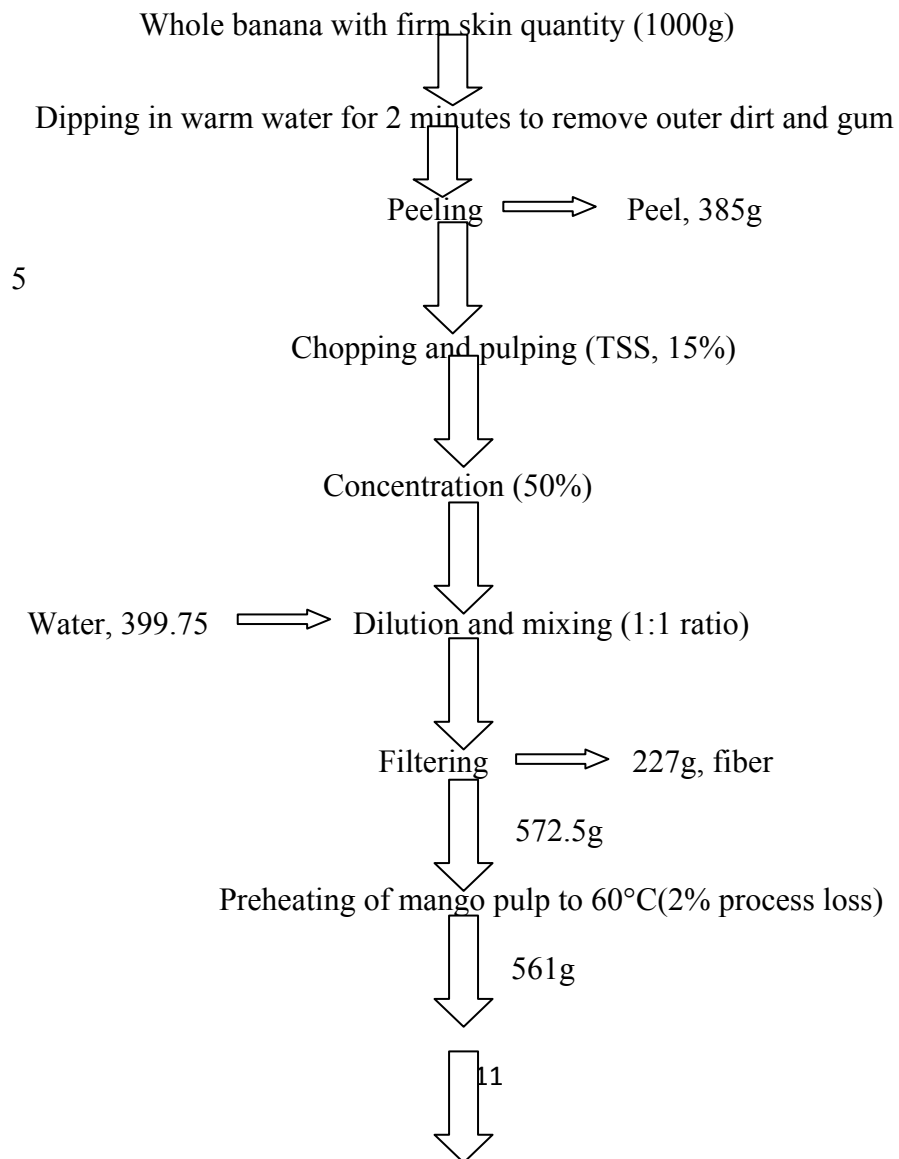
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## Annex

### Annex- 1 Process and material flowchart for mango powder production



Annex-2 Process and material flowchart for banana powder production.



### Spray drying and preheating

Annex-3 Effect of inlet temperature and flow rate on yield of improved mango powder Coefficients<sup>a</sup>

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
1 (Constant)	236.175	3.149		74.997	.008	196.162	276.188
Temperature	-.965	.015	-.901	-64.333	.010	-1.156	-.774
Flow rate	-1.550	.050	-.434	-31.000	.021	-2.185	-.915

a. Dependent Variable: Yield

Mango powder at 4%(wb)

(100g)

Annex-4 Effect of inlet temperature and flow rate on yield of banana powder Coefficients<sup>a</sup>

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
1 (Constant)	115.725	4.519		25.608	.025	58.305	173.145
temperature	-.550	.025	-.919	-22.000	.029	-.868	-.232

flowrate	-.783	.083	-.393	-9.400	.047	-1.842	.276
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a. Dependent Variable: yield

### Annex-5 Effect of inlet temperature and flow rate on solubility of mango powder

Coefficients<sup>a</sup>

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	459.100	4.199		109.341	.006	405.749	512.451
	temperature	-1.850	.020	-.999	-92.500	.007	-2.104	-1.596
	flowrate	-.267	.067	-.043	-4.000	.008	-1.114	.580

a. Dependent Variable: solubility

### Annex-6 Effect of inlet temperature and flow rate on solubility of banana powder

Coefficients<sup>a</sup>

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	336.162	2.079		161.713	.004	309.749	362.576

temperature	-1.508	.012	-.998	-131.174	.005	-1.655	-1.362
flow rate	-.285	.038	-.057	-7.435	.045	-.772	.202

a. Dependent Variable: solubility

Annex-7 Effect of inlet temperature and flow rate on bulk density of mango powder

Coefficients<sup>a</sup>

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.665	.052		12.679	.030	-.001	1.332
	temperature	-.002	.000	-.948	-6.680	.045	-.005	.002
	flow rate	.002	.001	.284	2.000	.029	-.009	.012

a. Dependent Variable: density

Annex-8 Effect of inlet temperature and flow rate on moister content of mango powder

Coefficients<sup>a</sup>

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
1 (Constant)	7.613	.525		14.504	.044	.944	14.281
temperature	-.023	.002	-.705	-9.000	.040	-.054	.009
flow rate	.075	.008	.705	9.000	.050	-.031	.181

a. Dependent Variable: moister

Annex-9 Effect of inlet temperature and flow rate on moister content of banana powder

Coefficients<sup>a</sup>

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
1 (Constant)	10.438	.452		23.097	.028	4.695	16.180
temperature	-.048	.003	-.903	-19.000	.033	-.079	-.016
flowrate	.075	.008	.428	9.000	.040	-.031	.181

a. Dependent Variable: moiter

### **Declaration**

I, the undersigned, declare that this thesis is my original work, has not been presented for a degree in any other University, and that all sources of materials used for the thesis have been duly acknowledged.

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Place: Addis Ababa

Date of submission: \_\_\_\_\_

This thesis has been carried out under my supervision and submitted for examination with my approval as University Advisors.

Name: \_\_\_\_\_

Signature:

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