PRODUCTION OF MANGIFERA INDICA POWDER USING SPRAY DRYER AND THE EFFECTS OF DRYING ON ITS PHYSICAL PROPERTIES

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JUDUL : PRODUCTION OF MANGIFERA INDICA POWDER USING SPRAY DRYER AND THE EFFECTS OF DRYING ON ITS PHYSICAL PROPERTIES

SESI PENGAJIAN : 2008/2009

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PRODUCTION OF MANGIFERA INDICA POWDER USING SPRAY DRYER AND THE EFFECTS OF DRYING ON ITS PHYSICAL PROPERTIES

SITI NADIRAH BINTI MD ZAINI

A thesis submitted in partial fulfillment of the
requirements for the award of the degree of
Bachelor of Chemical Engineering

Faculty of Chemical and Natural Resources Engineering
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APRIL 2009

`I declare that this dissertation entitled "Production of *Mangifera Indica* Powder using Spray Dryer and The Effects of Drying on Its Physical Properties" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my beloved mother and father.

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ABSTRACT

The objective of this work was to study the influence of spray drying conditions on the physical properties of mango powder. The process was carried out on a mini spray dryer and maltodextrin 10DE was used as carrier agent. Three tests were made. Solubility, dissolution and moisture content were analyzed as responses. Solubility was positively affected by inlet air temperature while dissolution and moisture content of powders were negatively affected by inlet air temperature. An increase in maltodextrin concentration increases the solubility of the mango powders and decreases the dissolution of the powders. From the result obtain the inlet air temperature of 160^{o}C and 15% of maltodextrin addition is the optimum value for this study. For the solubility test, the optimum value is at temperature of 170^{o}C and 20% of maltodextrin addition which the percentage of solubility is 81.76. The inlet air temperature of 150^{o}C and maltodextrin addition of 10% is the optimum value for the dissolution test. For moisture content analysis, the optimum value is at inlet air temperature of 160^{o}C and 15% maltodextrin addition which the percentage of moisture content is 2.38.

ABSTRAK

Objektif penyelidikan ini adalah untuk mengkaji pengaruh keadaan *'spray drying'* kepada ciri-ciri fizikal serbuk mangga. Proses ini menggunakan *'mini spray dryer'* dan maltodextrin 10DE sebagai agen pembawa. Tiga analisis telah dijalankan. Keterlarutan, pembubaran dan kandungan kelembapan dianalisis sebagai tindak balas. Keterlarutan serbuk dipengaruhi secara positifnya oleh suhu udara masuk sementara pembubaran dan kandungan kelembapan serbuk dipengaruhi secara negatif oleh suhu udara masuk. Peningkatan kepekatan maltodextrin turut meningkatkan keterlarutan serbuk mangga dan menurunkan pembubaran serbuk mangga. Daripada keputusan yang diperolehi, suhu udara masuk, 160^{o}C dan kepekatan maltodextrin sebanyak 15% ialah nilai optimum untuk penyelidikan ini. Untuk analisis keterlarutan, nilai optimum ialah pada suhu 170^{o}C dan 20% kepekatan maltodextrin di mana peratus keterlarutan adalah 81.76. Suhu 150^{o}C dan 10% kepekatan maltodextrin merupakan nilai optimum bagi analisis pembubaran. Bagi analisis kandungan kelembapan, nilai optimum ialah 160^{o}C dan 15% kepekatan maltodextrin di mana peratus kandungan kelembapan adalah 2.38.

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CHAPTER 1

INTRODUCTION

1.1 Background

Mango or manako is a tropical fruit of the mango tree. The name 'mango' is from the Malayalam word *manga* which was introduced to Europe by the Portuguese from Calicut (Malabar Coast) in the late fifteenth Century (Oxford English Dictionary mango, n. 1). Mango with scientific name Mangifera Indica belongs to the Anacardiaceae family. The exact origins of the mango are unknown, but most believe that it is native to Southern and Southeast Asia owing to the wide range of genetic diversity in the region and fossil records dating back 25 to 30 million years (Chapter XX Mango). Has been known as national fruit in India, Bangladesh and Philippines, it also refer as the “foods of the gods” in the Hindu Vedas.

The mango is presumed to be the most commonly eaten fresh fruit worldwide. It is believed to be rich of nutritional source, containing many vitamins, minerals, and especially antioxidants, as well as enzymes such as magneferin and lactase which aid in digestion and intestinal health (Nutrient Glossary, Letter M). Raw mango with 100g (3.5oz) serving has 65 calories and about half the vitamin C found in oranges. It also contains more vitamin A than most fruits. The typical composition of guava is listed in Table 1.1 (USDA Nutrient database).

The mature mango can be recognized when it has a characteristic fragrance and smooth, thin and tough skin. The color of ripe flesh mangos is pale yellow to orange. Likes another popular fruits, mango can be eaten raw as dessert fruit or can be processed to various products such as juice, jams, jellies, nectars and preserves.

In order to meet the demand of the market throughout the year in all areas, mangos are preserved using different techniques. The main reason is mangos are perishable and cannot be marketed as fresh products. One of the common techniques to manage this problem is drying method. It is use to enhance the productivity and to increase shelf life of food, especially mangos fruit that is used for this research. It can control the moisture content by either removing moisture or binding it so that the food becomes stable to both microbial and chemical deterioration. High moisture content will lead to the drop of quality and, indirectly, to a decrease in quantity. The modern techniques such as spray drying, freeze drying and so on can be applied for this method.

The quality of the food also refers to its nutrient contents. Customers today are well educated and knowledgeable. They are conscious with the nutrients contents in the food that they take. For this reason, it is important to develop new nutritional food, maximize their nutrient content in both processing and storage and extend the shelf-life, thus to meet the requirement of the market. In this regard, the information on nutrient change in processing and storage will be of great importance.

Figure 1.1: Mango *(Mangifera Indica)*

Table 1.1: Raw Mango

Nutritional value per 100g (USDA Nutrient database)			
Energy 70 kcal 270 kJ			
Carbohydrates	17.00 g	Pantothenic acid (B5) 0.160 mg	3%
Sugars	14.8 g	Vitamin B6 0.134 mg	10%
Dietary fiber	1.8 g	Folate (Vit. B9) 14 μg	4%
Fat	0.27 g	Vitamin C 27.7 mg	10%
Protein	0.51 g	Calcium 10 mg	1%
Vitamin A equiv. 38 μg	4%	Iron 0.13 mg	1%
- β-carotene 445 μg	4%	Magnesium 9 mg	2%
Thiamin (Vit. B1) 0.058 mg	4%	Phosphorus 11 mg	11%
Riboflavin (Vit. B2) 0.057 mg	4%	Potassium 156 mg	3%
Niacin (Vit. B3) 0.584 mg	4%	Zinc 0.04 mg	0%

1.2 Problem statement

In tropical and subtropical countries a large amount of fruit and vegetables are produced which are extremely attractive from a commercial point of view, a typical example is mango. Although, with the seasonal problem, most of these products, in a mature state, present high water content, so they are having a tendency to decomposition by microorganisms, chemical and enzymatic reaction. For that reason, these products are extremely perishable and cannot be marketed or exported as fresh produce, generating post-harvest losses well over 20-30% (Agrianual, 2003).

Dehydration via spray drying is one common technique used in the food industry. Under optimal processing conditions, it has been proven to be an effective method to obtain various products. Conversion of these products into a dry particulate resulting in reduced volume and longer shelf life. However, drying process conditions for these products have not been determined to preservation purposes.

Fruit juice powder obtained by spray drying favors the yield of high sugar content solids, most of them present in amorphous state (Sebhatu, Anberg, and Ahlneck (1994). These sugars are very hygroscopic, having an effect on the functional characteristics of the dehydrated material, mainly its tendency to become sticky (stickiness) and forming high agglomerates. This tendency to agglomeration may become accentuated as the amorphous state sugar transforms into crystalline sugar through adsorption of small amounts of water. Moreover, these products also have some drawback in their functional properties, such as stickiness, hygroscopicity and solubility, making their packaging and utilization substantially difficult.

A continuously increasing demand for mango pulp and mango concentrate mostly used as a base material in the beverage industry, as a flavoring ingredient in the dairy industry, and in baby food formulations, is expected (Nanjundaswamy, A.M., 1998). Transportation costs can be reduced when shipping this product to distant markets. But there is still insufficient information about mango powders in the literature. Mango is a rich source of nutritional value, so drying operations must be carefully intended to preserve these nutritional properties. Nutrient retention in different temperature and after dried must be investigated to determine temperature effect and water activity level or moisture content effect on mango juice and to propose best drying process from the study.

1.3 Objectives

1. To produce mango powder using spray dryer
2. To study the effect of maltodextrin added to mango juice
3. To evaluate the effects of drying on physical properties.

1.4 Scope of study

In order to achieve the objective of the research, the following scopes have been identified:

1. Effect of inlet air temperature
2. Effect of maltodextrin concentration

1.5 Rational and significance

With the presence of modern technologies, this research gives many advantages to food industry and human life.

1. Production of new beverage product in food market which is mango drink powder.
2. Reduction of transportation cost to distant market.
3. Transformation form mango juice to mango powder help increasing the shelf life of the product.
4. Production of variety of food product from mango fruit such as formulated drink, flavored ingredient and baby foods.

CHAPTER 2

LITERATURE REVIEW

2.1 Drying

Drying is a method of food preservation that works by removing water from the food, which prevents the growth of microorganisms and decay. Drying food using the sun and wind to prevent spoilage has been known since ancient times. Water is usually removed by evaporation (air drying, sun drying, smoking or wind drying) but, in the case of freeze-drying, food is first frozen and then water is removed by sublimation.

Bacteria and micro-organisms within the food and from the air need the water in the food to grow. Drying effectively prevents them from surviving in the food. It also creates a hard outer-layer, helping to stop micro-organisms from entering the food.

2.2 Spray Drying

Spray drying is a very commonly applied, technical method used to dry aqueous or organic solutions, emulsions etc., in industrial chemistry and food industry. The examples of spray dried products that currently available are dry milk powder, detergents and dyes. Spray drying can be used to preserve food or simply as a quick drying method. It also provides the advantage of weight and volume reduction. The simple theory of spray drying is to transform the feed from a fluid state into a dried particulate form by spraying the feed into a hot drying medium. Intensive research and development during the last two decades has resulted in spray drying becoming a highly competitive means of drying a wide variety of products. The range of product applications continues to expand, so that today spray drying has connections with many things we use daily.

2.3 Spray drying principle

Spray drying involves evaporation of moisture from an atomized feed by mixing the spray and the drying medium. The drying medium is normally air. The drying proceeds until the desired moisture content is reached in the sprayed particles and the product is then separated from the air. The mixture being sprayed can be a solvent, emulsion, suspension or dispersion.

2.3.1 Dispersion of the feed solution in small droplets

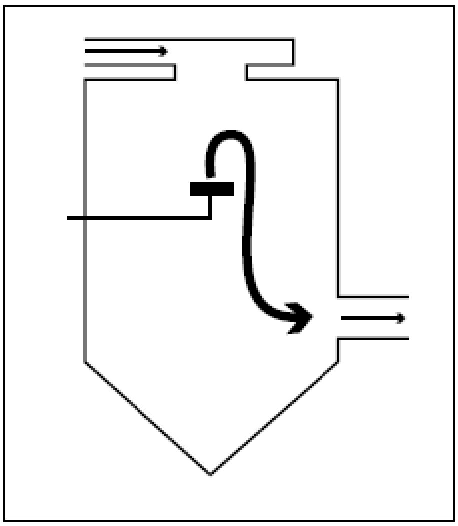
The complete process of spray drying basically can be categorized into four processes: The dispersion can be achieved with a pressure nozzle, a two fluid nozzle, a rotary disk atomiser or an ultrasonic nozzle. So, different kinds of energy can be used to disperse the liquid body into fine particles. The selection upon the atomiser type depends upon the nature and amount of feed and the desired characteristics of the dried product. The higher the energy for the dispersion, the smaller is the generated droplets.

2.3.2 Mixing of spray and drying medium (air) with heat and mass transfer

The manner in which spray contacts the drying air is an important factor in spray dryer design, as this has great bearing on dried product properties by influencing droplet behavior during drying.

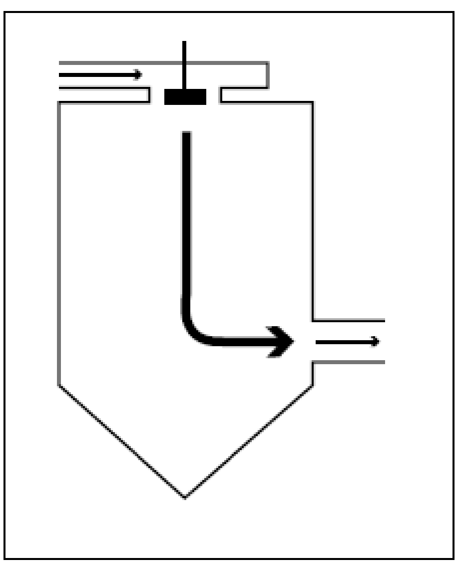
This mixing is an important aspect and defines the method of spray drying

Co-Current flow



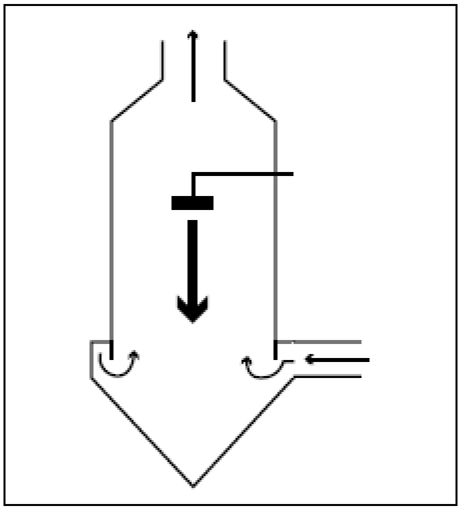
The material is sprayed in the same direction as the flow of hot air through the apparatus. The droplets come into contact with the hot drying air when they are the moistest. The product is treated with care due to the sudden vaporization.

Counter-Current flow



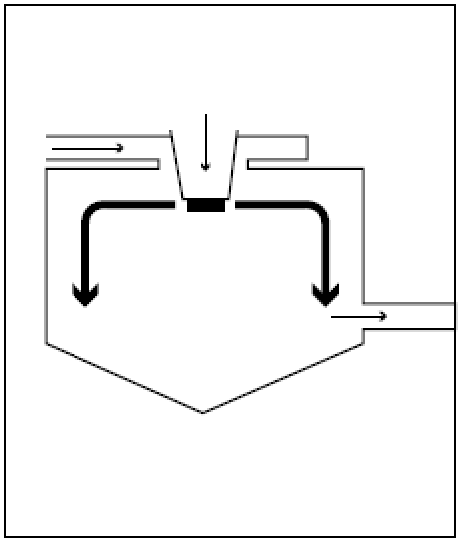
The material is sprayed in the opposite direction of the flow of hot air. The hot air flows upwards and the product falls through increasingly hot air into the collection tray. The residual moisture is eliminated, and the product becomes very hot. This method is suitable only for thermally stabile products.

Combined



The advantages of both spraying methods are combined. The product is sprayed upwards and only remains in the hot zone for a short time to eliminate the residual moisture. Gravity then pulls the product into the cooler zone. Due to the fact that the product is only in the hot zone for a short time, the product is treated with care.

Disk atomizer (rotary wheel)



The material to be sprayed flows onto a rapidly rotating atomizing disk and is converted to a fine mist. The drying air flows in the same direction. The product is treated with care, just as in the co-current flow method.

2.3.3 Open-cycle and closed cycle system

Air is mostly used as drying medium. The air stream is heated electrically or in a burner and after the process exhausted to atmosphere. This is an open-cycle system. If the heating medium is recycled and reused, typically an inert gas such as nitrogen, this is a closed-cycle system. These layout is typically chosen, when flammable solvents, toxic products or oxygen sensitive products are processed.

The most common type of spray dryer is the open-cycle, co-current spray dryer. In such a design, the atomised feed and the drying air is simultaneously injected into a spray drying chamber from the same direction.

2.3.4 Drying of spray (removal of moisture)

Evaporation takes place from the saturated vapor film which is quickly established at the droplet surface as soon as droplets of the spray come into contact with the drying air. Due to the high specific surface area and the existing temperature and moisture gradients, an intense heat and mass transfer results in an efficient drying. The evaporation leads to a cooling of the droplet and thus to a small thermal load. Drying chamber design and air flow rate provide a droplet residence time in the chamber, so that the desired droplet moisture removal is completed and product removed from the dryer before product temperatures can rise to the outlet drying air temperature. Hence, there is little likelihood of heat damage to the product.

2.3.4.1 Separation of product and air

In principal, two systems are used to separate the product from the drying medium:

1. Primary separation of the drying product takes place at the base of the drying chamber
2. Total recovery of the dried product in the separation equipment

Most common separation equipment is the cyclone. Based on inertial forces, the particles are separated to the cyclone wall as a down-going strain and removed. Other systems are electrostatic precipitators, textile (bag) filters or wet collectors like scrubbers.

2.3.5 Design of the Instrument

Diagram of the dry air flow

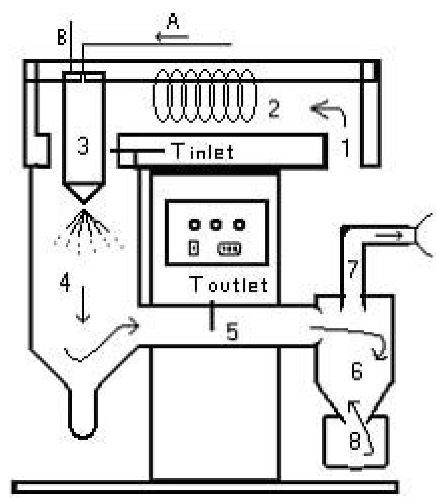
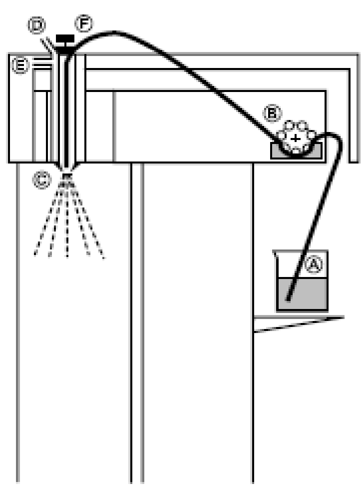


Diagram of the product flow and spray nozzle



(A) Solution, emulsion or dispersion of the product

(B) Peristaltic feed pump

(C) Two fluid nozzle (spray mist, spray cone)

(D) Compressed air or inert gas supply connection

(E) Cooling water connection

(F) Nozzle cleaning device, consisting of needle pneumatically pushed trough nozzle

2.3.6 Instrument settings

Spray Drying is a method where the result strongly depends upon the material properties. Thus, the instrument settings, namely inlet temperature, feed rate, spray air flow and aspirator flow are in a combined system influencing the product parameters:

- Temperature load
- Final humidity
- Particle size
- Yield

The optimizations of these parameters are usually made in a “Trial & Error” process. Some initial conditions can be found in the application database for equal or similar products.

Inlet temperature /outlet temperature

Inlet temperature is referring to the temperature of the heated drying air. The drying air is sucked or blowed in over a heater by the aspirator. The heated air temperature is measured prior to flowing into the drying chamber. When spray drying a solution, emulsion or dispersion the solvent is removed by vaporization.

The temperature of the air flow does not have to be higher than the boiling point of water to evaporate the individual drops during the short residence time. The gradient between wet surface and not saturated gas leads to an evaporation at low temperatures. The final product is separated and has no further thermal load.

The outlet temperature refers to the temperature of the air with the solid particles before entering the cyclone. This temperature is the resulting temperature of the heat and mass balance in the drying cylinder and thus cannot be regulated. Due to the intense heat and mass transfer and the loss of humidity, the particles can be regarded to have the same temperature as the gas. Thus, as a rule of thumb is: outlet temperature = maximum product temperature.

The outlet temperature is the result of the combination of the following parameters:

- Inlet temperature
- Aspirator flow rate (quantity of air)
- Peristaltic pump setting
- Concentration of the material being sprayed

The optimal choice for the temperature difference between the inlet and the outlet temperature is one of the most important points to consider when spray drying. Of course, other product specific factors, such as the melting point or decay temperature, must be taken into consideration. In spite of this, there is still some room for adjustment. The throughput of the device as well as the residual moisture content can be influenced within this temperature difference range.

Pump performance

The peristaltic pump feeds the spray solution to the nozzle. The pump's speed affects the temperature difference between the inlet temperature and the outlet temperature. The pump rate directly corresponds to the inlet mass. The higher the throughput of solution, the more energy is needed to evaporate the droplet to particles.

Thus, the outlet temperature decreases. The limitation of the pump is when the particles are not dry enough resulting in sticky product or wet walls in the cylinder. The pump throughput is also dependent upon various factors such as the viscosity of the spray solution and tubing diameter.

CHAPTER 3

METHODOLOGY

3.1 Introduction

For this research the type of method that is used is experimental method. Drying process is the main process to convert mango powder from mango juice. There are two part of this experiment. First, drying process of mango using spray drier in different temperature and secondly to evaluate the effects of drying on physical properties.

The main part of this research is to prepare mango powder from mango puree.

3.2 Material and Methods

3.2.1 Experimental Site

The experiment was conducted at the Bio-Scale Up Processing Laboratory 1&2 of the FKKSA's Laboratory the University Malaysia Pahang (UMP).

3.2.2 Raw Material

1. Mango that bought from the nearest retailer at the market. The ripe mango was chosen for this experiment.
2. Maltodextrin grade 10 have been used and it is bought from AAA SanSoon Seng Food Industries Sdn. Bhd (Sungai Buloh, Selangor).

Table 3.1: Specification of Maltodextrin Grade 10

Specification	
Dextrose Equivalent	9 - 12
Moisture, %	Max. 5.0
pH (20% Solution)	4.5 - 5.5
Sulphur Dioxide, ppm	Max. 10
Colour (O.D.)	Max. 2.0
Bulk Density (tapped), g/l	450 - 600
Shelf life	2 years
Raw material	Tapioca Starch
Storage condition	Cool & dry condition

3.2.3 Sample Preparation

Before being dehydrated, the juice was diluted in distilled water until reaching a total soluble solid content of 12ºBrix. The solution was placed in a tube and centrifuged at 5000 rpm during 10 min. Once the juice total solids were standardized, the following substances were added: Maltodextrin grade 10. Different percentage of maltodextrin was added; 0, 10, 15 and 20 percent.

3.2.4 Obtaining powders by spray drying

Powder was obtained by means of lab scale spray dryer (SD-06), with the flow of air drying parallel to the material feeding. The drying parameters were: input temperature = variable; output temperature = depends on input temperature; fan = 15 and pump = 5 remaining fixed during the experiment. The material obtained was stored in commercial bags (laminated sheet).

Figure 3.1: Spray dryer

3.2.5 Solubility Analysis

Solubility was determined according to the Eastman and Moore method (1984), with some modifications. To 100 ml of distilled H_2O, 1g of powder was added by mixing at high velocity in a mixer for 5 min. The solution was placed a tube and centrifuged at 3000 rpm during 5 min. An aliquot of 25 ml of the supernatant was placed in previously weighed Petri dishes and immediately oven-dried at 105 ºC, for 5 h. Solubility (%) was calculated by weight difference.

3.2.6 Dissolution Test

Dissolution is the process by which a solid or liquid forms a homogeneous mixture with a solvent (solution). This can be explained simply as a breakdown of the crystal lattice into individual ions, atoms or molecules.

The dissolution test measured the reconstitution speed of spray-dried powder into water. It is expressed as time taken by the powder to fully reconstitute in water by vortexing. The dissolution test in this research was modified from Al-Kahtani and Bakri (1990). About 50 mg of sample was weighed and place in a mini test tube. Then, 1mL of distilled water was added. This was followed by mixing using vortex at half speed. The time (s) to fully reconstitute the powders was recorded using an electronic timer. Triplicate samples were analyzed.

3.2.7 Moisture content

Powders and feed mixtures moisture contents in this research were determined gravimetrically by drying in a vacuum oven at 70^0C until constant weight is achieved. For mixtures moisture contents, 5ml of juices with different maltodextrin concentration was use as sample. While for powder, only 20mg of every powder that obtained was use as sample in this procedure. The moisture content in this experiment was determined based on AOAC Method. Triplicate samples of mango powder (20 mg each) and mango juice (5ml each with different maltodextrin concentration) were weighed and then dried in a vacuum oven at 70 ◦C for 24 h. The samples were removed from the oven, cooled and weighed. The drying and weighing processes were repeated until constant weigh were obtained.

These methods rely on measuring the mass of water in a known mass of sample. The moisture content is determined by measuring the mass of a food before and after the water is removed by evaporation:

$$\%\text{Moisture} = \frac{M_{\text{INITIAL}} - M_{\text{DRIED}}}{M_{\text{INITIAL}}} \times 100$$

EXPERIMENT FLOW CHART

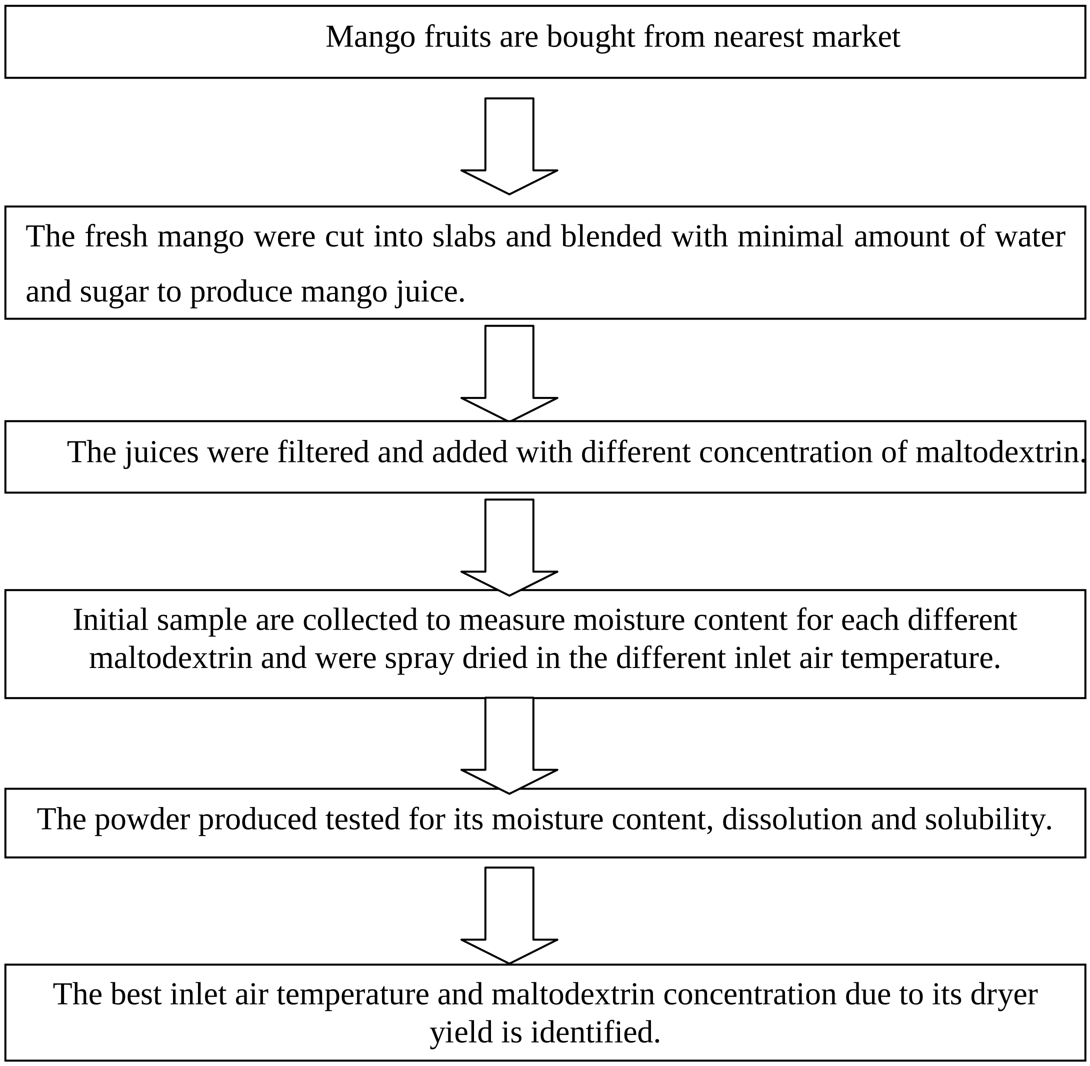


Figure 3.2: Schematic diagram for the process to convert mango juice to powder.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Spray Drying

Powder was obtained by means of lab scale spray dryer (SD-06), with the flow of air drying parallel to the material feeding. The drying parameters were: input temperature = variable; output temperature = depends on input temperature; fan = 15 and pump = 5 remaining fixed during the experiment. The result is as below:

Table 4.1: Summary of parameters and analysis result for powder obtained.

Parameter		Powder obtained				
Maltodextrin (%)	Inlet air temperature (^oC)	Outlet air temperature (^oC)	Weight of powder (g)	Solubility (%)	Time reconstitute (s)	Moisture content (%)
0	150	-	-	-	-	-
	160	-	-	-	-	-
	170	-	-	-	-	-
10	150	79	7.831	76.87	67.0	0.48
	160	81	1.217	77.55	82.3	0.31
	170	92	4.628	77.71	92.3	0.15
15	150	83	5.070	76.73	82.3	0.20
	160	89	5.456	78.27	92.7	0.10
	170	92	5.433	78.54	116.7	0.10
20	150	78	3.211	80.76	74.3	0.41
	160	88	3.662	80.92	81.0	0.10
	170	94	4.540	81.76	98.3	0.10

The quality of spray-dried food is quite dependent on the spray-dryer operating parameters. So, for this research, we need to make an assumption for the operating parameter to obtain the best product. The optimizations of these parameters are usually made in a "Trial & Error" process. We can found some initial conditions in the application database for equal or similar products and use the conditions to make our own assumption for our samples. Prediction of operating parameters such as inlet air temperature, airflow volume, pump speed, de-blocker frequency and the addition of suitable additive plays a main role in order to attain powder with high quality. But, for this research, we just highlight two main parameters which are inlet air temperature and addition of additive. In this research, we used maltodextrin grade 10 as additive.

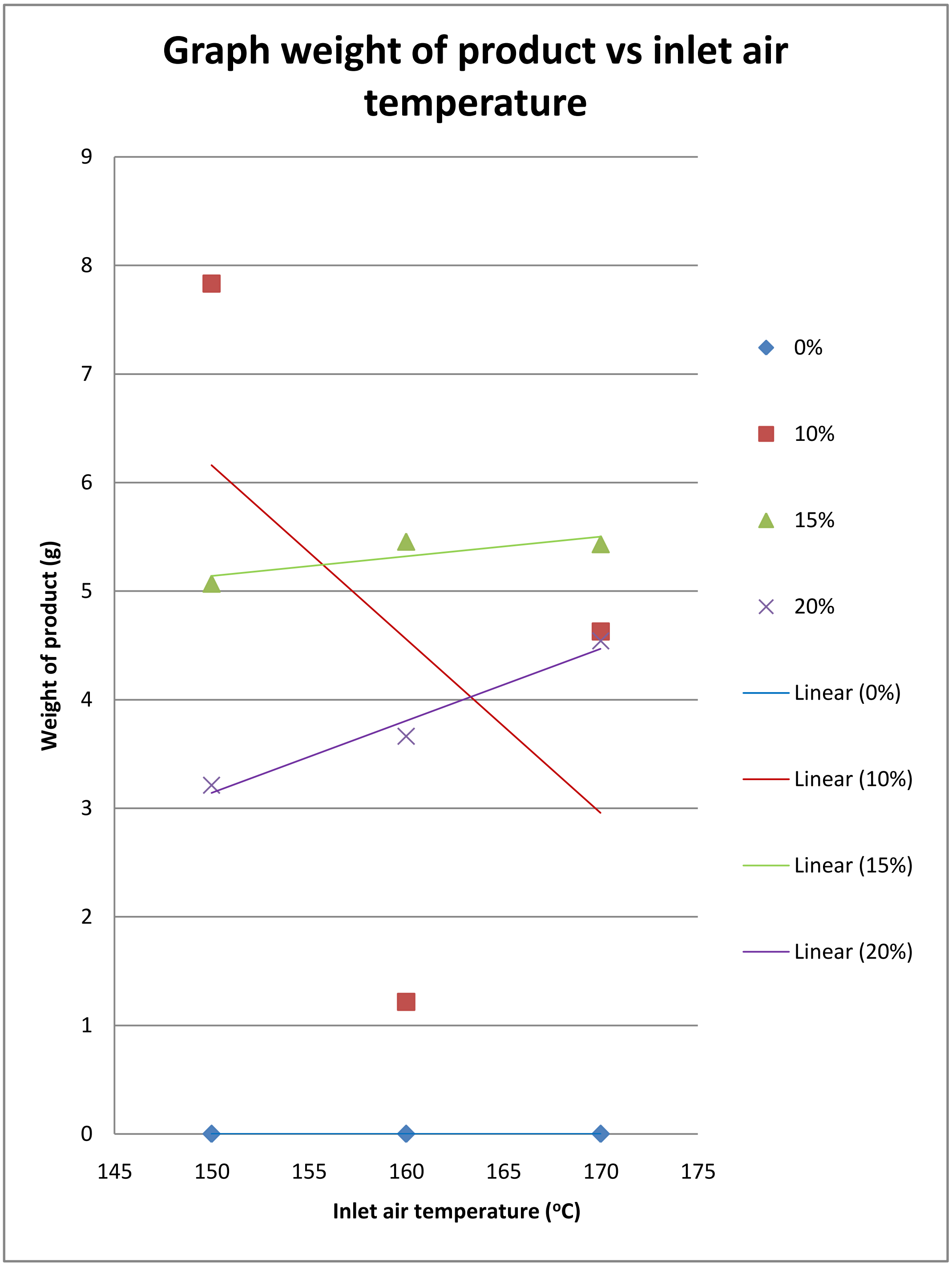


Figure 4.1: Graph weight of product versus inlet air temperature

The experiment was done for 300 ml of mango juice with various inlet air temperatures and various percentage of maltodextrin grades 10. The experiment was dividing into two parts. First part, the spray-dried of mango juice without maltodextrin addition. Second part was spray-dried of mango juice with maltodextrin addition. For the first part, no powder was produced at all. The same result obtained even when we change the inlet air temperature. This is due to product sticking to the walls of the drying chamber. Previous researches have demonstrated that spray-drying foods high in sugar has low efficiency because of this reasons. (Bhandari and others1997a; Vegaandothers 2005). However, in order to spray-dry sticky products, carriers such as maltodextrin (MD) can be used to facilitate the drying process. The high molecular weight of maltodextrin increases the glass transition temperature of the product (Bhandari and Howes 1999; Vega and others 2005). The result can be seen at Table 4.1. After addition of maltodextrin, powder was produced with different weight depends on the parameters. From the tabulated result, we can see that the highest powder weight is 7.831g at 150^{o}C inlet air temperature and 10% maltodextrin added. The lowest powder weight is 1.217g at 160^{o}C inlet air temperature and 10% maltodextrin added. From graph (Figure 4.1), we can conclude that the inlet air temperature of 160^{o}C and 15% of maltodextrin addition is the optimum value for this study. The weight of the powder attain is 5.456 g. This result is same with the result obtained from the journal.

4.2 Solubility Test

$$\% \text{ Water solubility} = \frac{\text{Weight of recovered solid (g)}}{\text{Weight of sample (g)}} \times 100\%$$

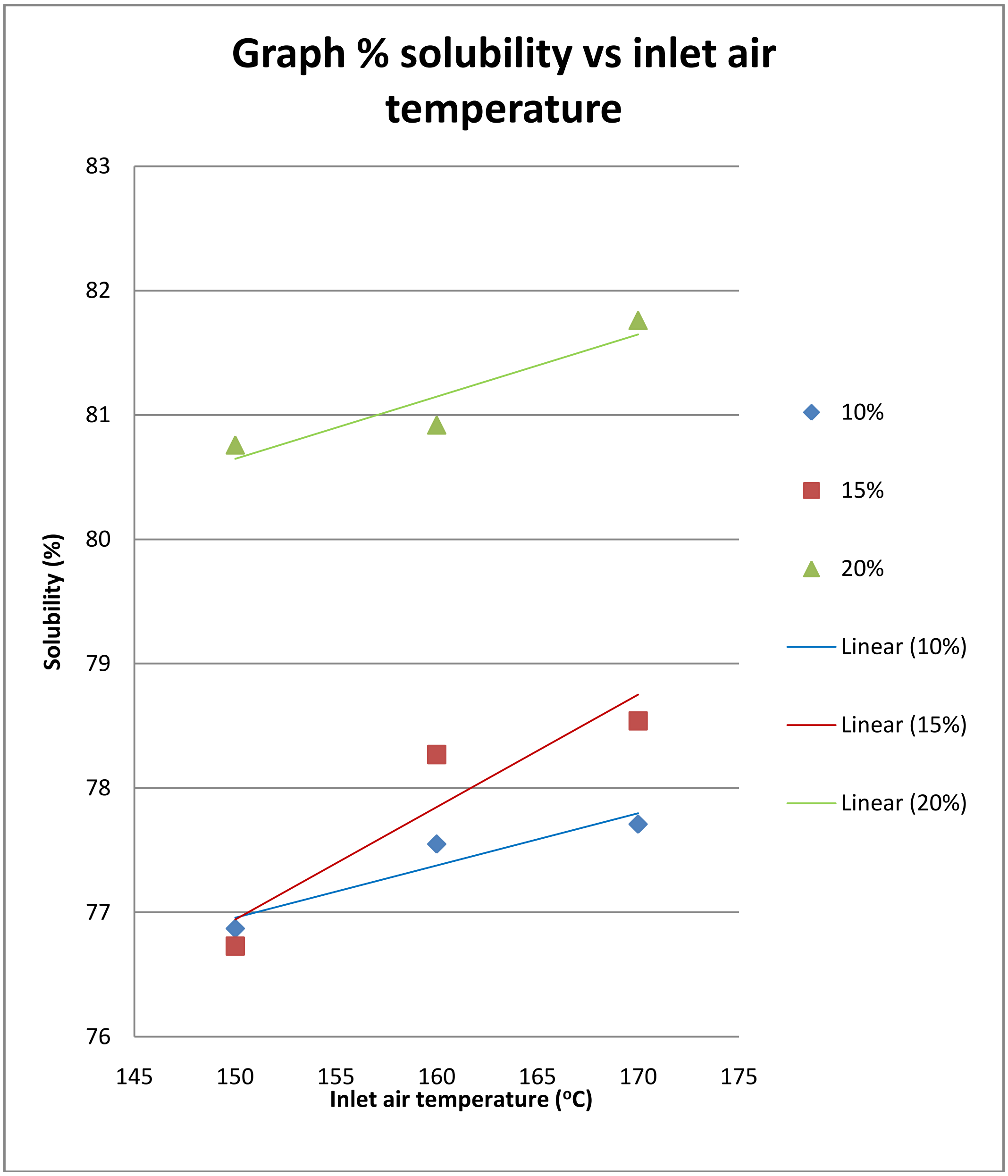


Figure 4.2: Graph percentage of solubility versus inlet air temperature

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. Figure 4.2 shows powdered mango solubility in function of inlet air temperature. It was verified that powdered mango solubility increases in function of inlet air temperature. This is due to the effect of inlet air temperature on residual moisture content. The lower the powder moisture content, the more soluble is the powder. This figure also shows the addition of maltodextrin during spray-drying of mango impacted the solubility of the mango powders. The instant properties of a powder involve the ability of a powder to dissolve in water. Most powdered foods are intended for rehydration; therefore, the ideal powder would wet quickly and thoroughly, sink rather than float, and disperse/dissolve without lumps (Hogekamp and Schubert 2003). Addition of maltodextrin increased the solubility of the mango powders. Conversely, adding maltodextrin will reduce the water-holding capacity of the mango powders (Table 4.2 in Appendix). These effects of maltodextrin can be attributable to the inverse relationship between the maltodextrin concentration and the mean diameter of the particles. Maltodextrin can form outer layers on the drops and alter the surface stickiness of particles due to the transformation into glassy state (Adhikari and others 2003). The changes in surface stickiness reduce the particle–particle cohesion and particle–wall adhesion during spray-drying, resulting in less agglomerate formation and, therefore, lower water-holding capacity of the powders. From the graph (Figure 4.2), it shows that the highest percentage of solubility is 81.76 with inlet air temperature 170^{o}C and 20% maltodextrin addition while for the lowest percentage of solubility is 76.87 for 150^{o}C inlet air temperature and 10% maltodextrin addition. From this result, the optimum value for solubility test is at temperature of 170^{o}C and 20% of maltodextrin addition which the percentage of solubility is 81.76. Result obtained proved the reason given before which is increasing inlet air temperature and maltodextrin concentration leads to increasing of solubility percentage.

4.3 Dissolution Test

The dissolution test measured the reconstitution speed of spray-dried powder into water. It is expressed as time taken by the powder to fully reconstitute in water by vortexing. The result is shown below:

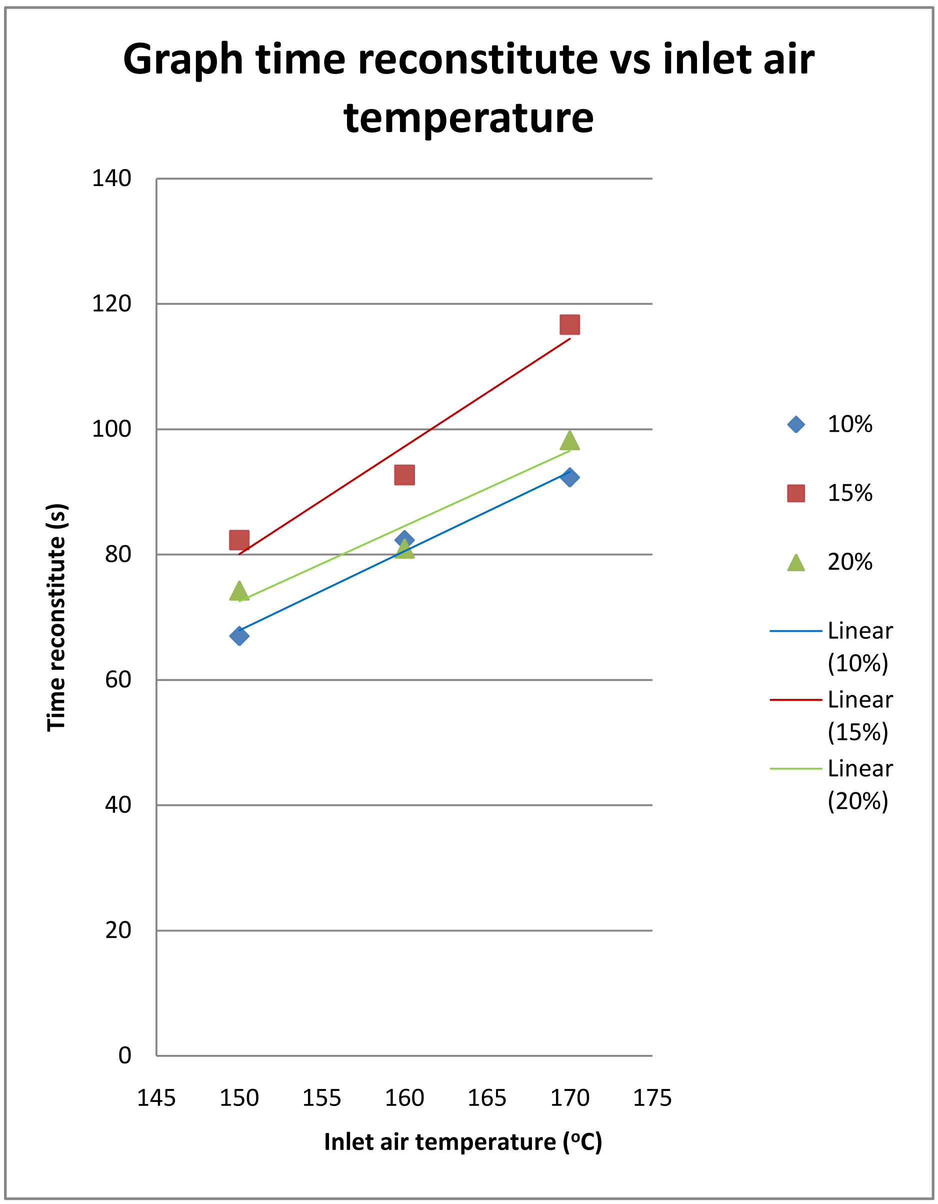


Figure 4.3: Graph time reconstitute versus inlet air temperature for dissolution test

From the result in Figure 4.3, the highest dissolution of powder is refer to the powder that have lowest time of reconstituted which is 67s for 150^{o}C inlet air temperature and 10% maltodextrin addition. At 170^{o}C inlet air temperature and 15% maltodextrin addition, the powders have the highest time of reconstituted which is 116.7s. From the result obtained, we can conclude that as the inlet air temperature increase, the time reconstitute also increase, which means the dissolution of powder, decreased. This is because at higher inlet air temperature, hard surface layer might be formed over the powder particle. This surface layer will prevent water molecules from diffusing through the particle. While at lower inlet air temperature, evaporation rate was slower, so it will produce powders with high moisture content. This powder have higher tendency of agglomeration which helped to increase the reconstitution of the powders. So, that makes times taken to fully reconstitute were relatively slow at lower inlet air temperature. For this result, the inlet air temperature of 150^{o}C and maltodextrin addition of 10% is the optimum value for the dissolution test. The time reconstitute of the powders is 67s.

4.4 Moisture Content Test

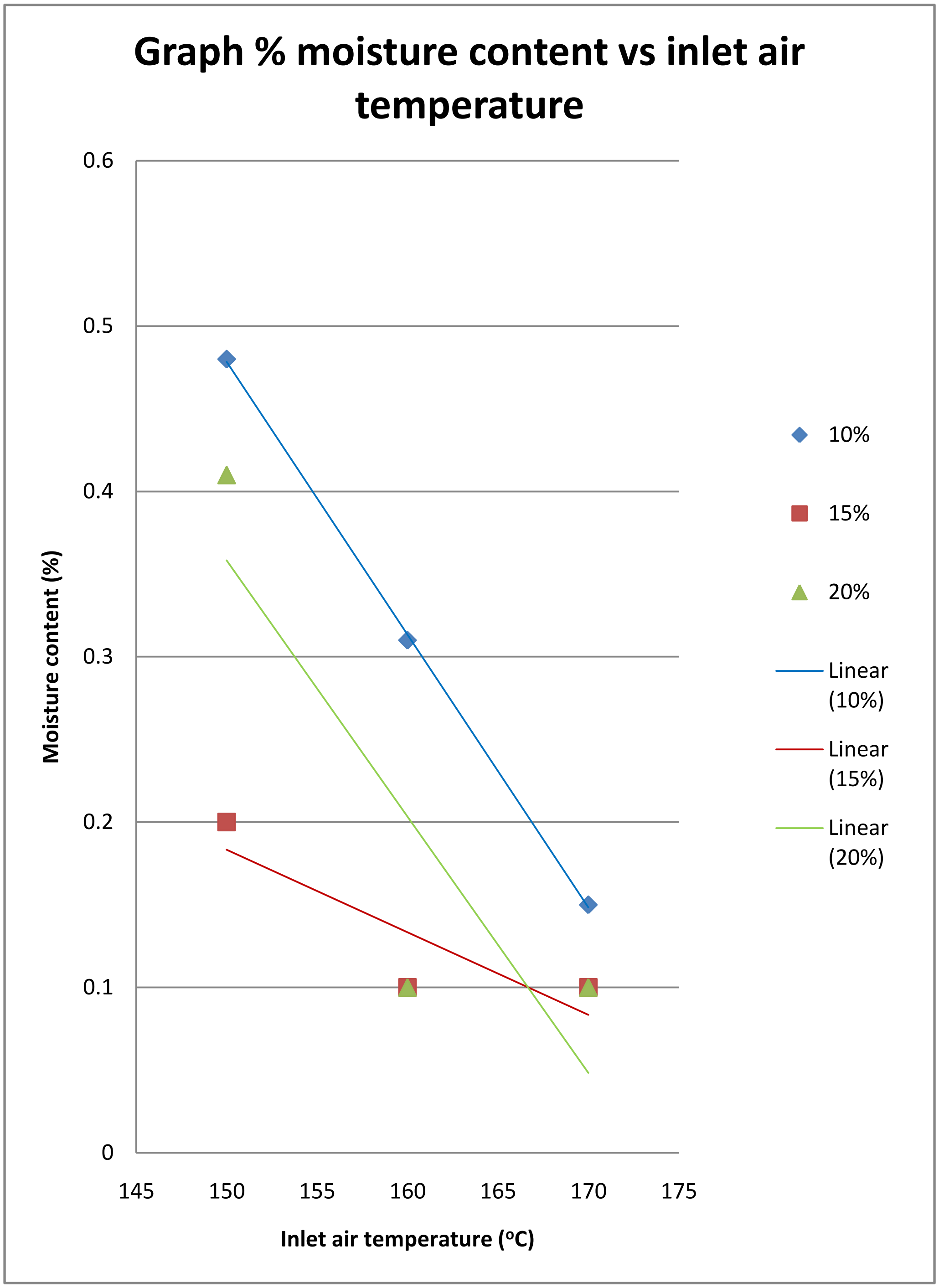


Figure 4.4: Graph percentage of moisture content versus inlet air temperature

Figure 4.4 shows powdered mango moisture content in function of inlet air temperature. It was verified that powdered mango moisture content decrease in function of inlet air temperature. The highest moisture content is 0.48%, for 150^{o}C inlet air temperature and 10% maltodextrin addition whereas; the lowest moisture content is 0.10%. This is happen due to several reasons. First, moisture content was drastically influenced by inlet air temperature and feed flow rate. Temperature was the variable that showed the greatest influence on powders moisture content compared to feed flow rate. Since our scope is to study the effect of inlet air temperature to the powders, we pay more attention to the effect of temperature than feed flow rate. At higher inlet air temperatures, there is a greater temperature gradient between the atomized feed and the drying air, resulting in a greater driving force for water evaporation and thus producing powders with lower moisture content. Secondly, moisture content also decreased with increasing maltodextrin concentration. Powders that have lower moisture content are a good quality powders. So, from the result obtain, at inlet air temperature of 160^{o}C and 15% maltodextrin addition is the optimum value for moisture content analysis which the percentage of moisture content is 0.10.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The effect of the spray-dryer operating parameters such as inlet air temperature and addition of additive likes maltodextrin on mango juice powder physical properties such as weight obtained, solubility, residual moisture content and dissolution are investigated. The results show that all of the operating parameters affect the powder physical properties significantly. An increase in inlet air temperature increases the solubility of the powders and decreases dissolution and moisture content of powders. An increase in maltodextrin addition increases the solubility of the mango powders and decreases the dissolution of the powders.

From the result obtain the inlet air temperature of 160^{o}C and 15% of maltodextrin addition is the optimum value for this study. For the solubility test, the optimum value is at temperature of 170^{o}C and 20% of maltodextrin addition which the percentage of solubility is 81.76. The inlet air temperature of 150^{o}C and maltodextrin addition of 10% is the optimum value for the dissolution test. For moisture content analysis, the optimum value is at inlet air temperature of 160^{o}C and 15% maltodextrin addition which the percentage of moisture content is 2.38%.

The produced spray dried product has very good commercial value in our neighborhood seeing that fruit powders immensely utilized to make blended juice and as an infant product in western countries. So, it is important to determine the optimum temperature and reaction time because it will lead to the highest yield and quality of the product.

5.2 Recommendation

The puree added with maltodextrin to facilitate non hygroscopic or to reduce stickness. The glass transition approach is the recent technique to describe stickiness and applied to the spray drying process. Therefore, it is recommended here that some experiments be conducted with proportion of maltodextrin and find the interrelationships among glass transition temperature Tg, water activity and nutrient retention.

Stickiness is related to the material property (**Dr Bhesh Bhandari**). It can be correlated to glass transition temperature. An empirical approach can be used to optimize the processing condition- however the Tg concept can be more appropriate. Drying parameters and drier design influence the stickiness property of droplet. Further research is needed to correlate the stickiness property with the Tg, drying parameters, drying kinetics, evolution of surface property of droplets.

It is also important to focus the research in minimizing nutrient loss in processing from nutrient retention study to customer demand.

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http://en.wikipedia.org/wiki/Spray_dryer

APPENDIX A

Production of Powders

Volume Juice= 300ml

Fan Setting= 15

Pump Setting= 5

Parameter		Powder obtained	
Maltodextrin (%)	Inlet air temperature (^oC)	Outlet air temperature (^oC)	Weight of powder (g)
0	150	-	-
	160	-	-
	170	-	-
10	150	79	7.831
	160	81	1.217
	170	92	4.628
15	150	83	5.070
	160	89	5.456
	170	92	5.433
20	150	78	3.211
	160	88	3.662
	170	94	4.540

Dissolution Test

Mass of Powder = 50mg

Volume of Distilled Water = 1ml

Parameter		Time reconstitute (s)			
Maltodextrin (%)	Temperature (^{o}C)	First trial	Second Trial	Third trial	Average
10	150	57	61	83	67.0
	160	83	80	84	82.3
	170	121	76	80	92.3
15	150	71	109	67	82.3
	160	122	70	86	92.7
	170	132	129	89	116.7
20	150	108	59	56	74.3
	160	83	70	90	81.0
	170	109	94	92	98.3

Moisture Content Test for Powders Produced

Parameter		% Moisture content		
Maltodextrin (%)	Temperature (°C)	First trial	Second trial	Average
10	150	0.45	0.51	0.48
	160	0.41	0.21	0.31
	170	0.20	0.10	0.15
15	150	0.10	0.30	0.20
	160	0.10	0.10	0.10
	170	0.10	0.10	0.10
20	150	0.41	0.40	0.41
	160	0.10	0.10	0.10
	170	0.10	0.10	0.10

Solubility Test

Parameter		Solubility (%)			
Maltodextrin (%)	Temperature (^oC)	First trial	Second trial	Third trial	Average
10	150	76.62	77.00	77.00	76.87
	160	76.5	78.60	77.55	77.55
	170	77.12	78.50	77.50	77.71
15	150	77.27	76.70	76.22	76.73
	160	76.30	77.70	80.80	78.27
	170	76.00	79.22	80.40	78.54
20	150	76.69	77.00	88.60	80.76
	160	76.55	78.10	88.10	80.92
	170	76.17	77.90	91.21	81.76