SPRAY DRIED DURIAN POWDER

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SPRAY DRIED DURIAN POWDER

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Thesis submitted to the Faculty of Chemical and Natural Resources Engineering in Partial Fulfillment of the Requirement for the Degree of Bachelor Engineering in Chemical Engineering

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I declare that this thesis entitled "Spray dried durian powder" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree ans is not concurrently submitted in candidature of any other degree.

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Date : 11 APRIL 2010

To my beloved father and mother

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ABSTRACT

This study explains the process and the best parameteres to dry durian juice using laboratory scale spray dryer. The raw durian fruit bought is blended in the lab to squeeze out the juice before the process of spray dying. Calcium Carbonate is used as the anti-caking agent. In this process various ratio of durian to water and amount of maltodextrin is used and added to identify the best ratio of durian to water and amount of maltodextrin that should be added to make durian juice. Once the ratio of durian to water and amount of maltodextrin is determined, the variation in the temperature is done to find out the best temperature. For the part of analytical experiment, solubility analysis is done using the lab scale centrifugal machine. Solubility analysis is done on the best powder obtained. The final analysis done is the sensory evaluation. In this evaluation, students were randomly picked in the cafeteria. They were given the reconstituted juice and the produced powder to evaluate. The criteria being evaluated in this part are the appearance, flavor and the texture. The students were asked to rank all this categories following the scale of 1 to 5. From this evaluation the commercial value of produced durian powder can be studied. The powder is then stored in shelf for one month. From this research, it was found that durian juice can be powderised using the lab scale spray dryer. The suitable ratio of durian to water and amount of maltodextrin is 1:1 and 10% respectively and the best temperature is at 170°C. Durian powder has a solubility of 75.6% and that it has commercial values and can be marketed.

ABSTRAK

Kajian yang dijalankan adalah untuk mengetahui cara dan parameter terbaik untuk menghasilkan serbuk durian menggunakan alat pengering sembur yang terdapat di makmal. Buah durian dibeli dari kedai berdekatan dan dikisar di makmal sebelum prosess menjadikan serbuk. Jus kemudian ditambahkan dengan kalsium karbonat sebagai ejen untuk mengelakkan kepulan dalam serbuk yang dihasilkan. Dalam prosess ini nisbah durian kepada air dan kuantiti maltodextrin dimanipulasikan untuk mendapat nisbah dan kuantiti terbaik yang patut ditambahkan untuk menghasilkan serbuk durian. Setelah mengenalpasti nisbah durian kepada air dan kuantiti maltodextrin yang terbaik, prosess diteruskan untuk mengenalpasti suhu terbaik. Eksperiment dijalankan beberapa kali dengan suhu berbeza untuk mendapatkan suhu yang terbaik. Untuk bahagaian analitikal, kadar keterlarutan serbuk dianalisis. Eksperiment ini dijalankan dengan menggunakan alat centrifugal yang terdapat dalam makmal. Eksperiment ini dijalankan menggunakan serbuk yang terbaik yang telah dihasilkan. Analisis terakhir yang dijalankan adalah ujian deria. Seramai 10 orang pelajar UMP dipilih secara rawak di kafeteria. Setiap pelajar diberikan jus durian yang dihasilkan melalui serbuk durian yang dihasilkan. Kriteria yang dianalisis dalam kajian ini adalah mengenai warna, saiz, bentuk rasa, kelikatan dan juga bau serbuk dan jus yang dihasilkan. Keputusan yang diterima digunakan untuk mengkaji ciri-ciri serbuk durian untuk tujuan komersial. Pada akhir kajian ini didapati 1:1, 10% dan 170°C, adalah nisbah, kuantiti maltodextrin dan suhu terbaik untuk melakukan eksperiment ini. Keterlarutan serbuk yang dihasilkan adalah 75.6% dan juga mempunyai nilai komersial yang tinggi dan produk ini boleh dipasarkan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

In this part, an intoduction on the durian tree will be presented.

1.1 Background of durian

There are 30 recognised *Durio* species, at least nine of which produce edible fruit. *Durio zibethinus* is the only species available in the international market, other species are sold in their local regions. There are hundreds of durian cultivars, many consumers express preferences for specific cultivars, which fetch higher prices in the market.

The durian has been known and consumed in southeastern Asia since prehistoric times, but has only been known to the western world for about 600 years. The earliest known European reference to the durian is the record of Niccolò Da Conti, who travelled to southeastern Asia in the 15th century (Brown, Michael J., 1997).

The Portuguese physician Garcia de Orta described durians in *Colóquios dos Simples e Drogas da India* published in 1563. In 1741, *Herbarium Amboinense* by the German botanist Georg Eberhard Rumphius was published, providing the most detailed and accurate account of durians for over a century. The genus *Durio* has a complex taxonomy that has seen the subtraction and addition of many species since it was created by Rumphius (O'Gara, E., Guest, D. I. and Hassan, N. M., 2004). During the early stages of its taxonomical study, there was some confusion between durian and the soursop (*Annona muricata*), for both of these species had thorny green fruit (Brown, Michael J., 1997). It is also interesting to note the Malay name for the soursop is *durian Belanda*, meaning *Dutch durian* (Davidson, Alan, 1999). In the 18th century, Johann Anton Weinmann considered the durian to belong to Castaneae as its fruit was similar to the horse chestnut.

Durians originated from Brunei, Malaysia and Indonesia. The flesh can be consumed at various stages of ripeness, and is used to flavour a wide variety of savoury and sweet edibles in Southeast Asian cuisines such as soup, candy, pastries and ice cream. A traditional way of preparing durian is to cook it with sticky rice and sugar in coconut milk, which apparently helps neutralize the unpleasant smell. Durian is also rich in dietary fiber, which makes it a good bulk laxative. The fiber content helps to protect the colon mucous membrane by decreasing exposure time as well as binding to cancer causing chemicals in the colon. It is also rich in vitamin C.

Table 1.1: Nutrient content

Durian fruit, Nutritive Value per 100 g.

Principle	Nutrient Value	Percentage of RDA
Energy	147 Kcal	7%
Carbohydrates	27.09 g	21%
Protein	1.47 g	2.5%
Total Fat	5.33 g	20%
Cholesterol	0 g	0%
Dietary Fiber	3.8 g	**10%**
Vitamins		
Folates	36mcg	9%
Niacin	1.074 mg	7%
Pantothenic acid	0.230 mg	4.5%
Pyridoxine	0.316 mg	**24%**
Riboflavin	0.200 mg	15%
Thiamin	0.374 mg	31%
Vitamin C	19.7 mg	**22%**
Vitamin A	44 IU	1.5
Electrolytes		
Potassium	436 mg	**9.5%**
Sodium	2 mg	0%
Minerals		
Calcium	6 mg	0.6%
Copper	0.207 mg	**23%**
Iron	0.43 mg	5%
Magnesium	30mg	7.5%
Manganese	0.325mg	**14%**
Phosphorus	39 mg	6%
Zinc	0.28 mg	2.5%
Phyto-nutrients		
α-Carotene	6 mcg	--
β-Carotene	23 mcg	--

Source: USDA National Nutrient database (Opens new windov

However, there is an increasing demand for this “king of fruits” among the Western consumers. In order to meet this demand, modern techniques have been used on the fruit such as canning and freezing while still retaining its taste, appearance and nutritive value. But drying is an excellent way to transport the fruit because it takes much less storage space than canned or frozen fruits. Dried durian can be kept well and longer because of the moisture content is so low that can prevent the growth of microorganisms.

There are many types of drying , each with their own advantages for particular applications such as bed dryers, fluidized bed dryers, freeze drying, shelf dryers, spray drying, sunlight, commercial food dehydrators and household oven. Of all stated, spray drying is choosen because it is a method that produce a dry fruit in a form of a “dehydrated” powder from the durian flesh that has been pre-made into liquid by rapidly drying with a hot gas. It has become the most important technique for dehydrating fluid foods and is used extensively in the pharmaceutical for antibiotics, medical ingredients, additives and chemical industries like paint pigments, ceramic materials, catalyst supports. Exporting of durian had also begun along time ago.

1.1.1 Description

1.1.1.1 Trees

Durian trees are large, growing to 25–50 metres (80–165 ft) in height depending on the species (Brown, Michael J., 1997). Durian trees have one or two flowering and fruiting periods per year, though the timing varies depending on the species, cultivars, and localities. The durian is also somewhat similar in appearance to the jackfruit, an unrelated species.

1.1.1.2 Leaves

The leaves are evergreen, elliptic to oblong and 10–18 centimetres (4–7 in) long. The evergreen, alternate leaves are oblong-lance-olate, or elliptic-obovate, rounded at the base, abruptly pointed at the apex; leathery, dark-green and glossy above, silvery or pale-yellow, and densely covered with gray or reddish-brown, hairy scales on the underside; 2 1/2 to 10 in (6.25-25 cm) long, 1 to 3 1/2 in (2.5-9 cm) wide. In Malaya, a decoction of the leaves and roots is prescribed as a febrifuge. The leaf juice is applied on the head of a fever patient. The leaves are employed in medicinal baths for people with jaundice. Decoctions of the leaves and fruits are applied to swellings and skin diseases. The ash of the burned rind is taken after childbirth. The leaves probably contain hydroxy-tryptamines and mustard oils.

1.1.1.3 Flowers

The flowers are produced in three to thirty clusters together on large branches and directly on the trunk with each flower having a calyx (sepals) and five (rarely four or six) petals. Durian flowers, which are strongly fragrant, are 2 to 3 inches [50-70 mm] long and grow in stalked clusters of 1 to 45 individual flowers per cluster. These flower clusters hang from the main and smaller branches, or directly from the trunk of the tree. A period of 3 to 4 weeks dry weather is needed to stimulate flowering. It takes about one month for a durian flower to develop from first appearance as a tiny bud to an open blossom. As it matures, the outer fleshy part of the flower (the epicalyx) splits to reveal 5 united sepals and 5 petals, which match the color of the edible pulp that will develop inside the fruit, trees with yellowish flowers produce yellow-fleshed durians (the most common), while those with white or reddish petals will have white or reddish fleshed fruit. Durian flowers are hermaphrodites, each having a stamen and pistil in the same flower. However, self-pollination rarely happens, for when the flowers are open, normally from 3 p.m. to about midnight, the pistil and the stamen do not appear at the same time. The female stigma from the pistil usually comes out first, long before the anthers of the stamen appear and shed their pollen, by the time the pollen is active, the stigma is no longer receptive. By midnight most pollen has been shed and all flower parts except the pistil fall to the ground.

1.1.1.4 Fruits

A typical durian tree can bear fruit after four or five years. The durian fruit can hang from any branch and matures roughly three months after pollination. The fruit can grow up to 30 centimetres (12 in) long and 15 centimetres (6 in) in diameter, and typically weighs one to three kilograms (2 to 7 lb) (Brown, Michael J., 1997). Its shape ranges from oblong to round, the colour of its husk green to brown, and its flesh pale-yellow to red, depending on the species (Brown, Michael J., 1997). Among the thirty known species of *Durio*, nine of them have been identified as producing edible fruits: *D. zibethinus*, *D. dulcis*, *D. grandiflorus*, *D. graveolens*, *D. kutejensis*, *D. lowianus*, *D. macrantha*, *D. oxleyanus* and *D. testudinarum* (O'Gara, E., Guest, D. I. and Hassan, N. M., 2004). However, there are many species for which the fruit has never been collected or properly examined, so other species with edible fruit may exist (Brown, Michael J., 1997).

1.1.1.5 Husks

The term 'Durian' has been derived from the Malay word 'duri' which means thorn. This is because the fruit features a tough, thick, thorny husk that bears semblance to the husk of a jackfruit. The durian is a tropical fruit encased in a spherical or ovoid spiny hard shell, which can be quite large, a single unhusked durian can be the size of a football. Within the shell are five or six segments of golden or cream-colored custardy pulp, the flavor of which is reputed to be so delectable that it is commonly known in Southeast Asia as the "king of fruits." But perhaps even more notable about the durian than its taste is its remarkably foul odor.

1.1.1.6 Arils

The durian is a tropical fruit encased in a spherical or ovoid spiny hard shell, which can be quite large—a single unhusked durian can be the size of a football. Within the shell are five or six segments of golden or cream-colored custardy pulp, the flavor of which is reputed to be so delectable that it is commonly known in Southeast Asia as the "king of fruits." But perhaps even more notable about the durian than its taste is its remarkably foul odor.

1.2 Problem Statement

The durian is the fruit of several tree species belonging to the genus Durio and the Malvaceae family (although some taxonomists place Durio in a distinct family, Durionaceae). People famously described its flesh as "a rich custard highly flavoured with almonds". The growing of durian trees is limited due to its season (June – August), an extremely short shelf life (2-5 days), and the ultra-tropical climates. The trees also cannot be grown above an altitude of 2,600 ft (800 m). Because of this the durians are expensive. Exporting of durians are also limited since that there are no airlines that allow the transport of fresh durians even in the luggage compartment. In most cities Durian is banned in public places restaurants and hotels. The smell of the fruit is notoriously known by “revolting” odor but still craved by many who have been accustomed to it. Durian juice is currently produced in Thailand and it is the only company that produce Durian juice. This shows that Durian may have a greater market potential since there is an increasing demand for the fruit in the Western countries as we, Malaysia can also export Durian but in “dry” form because the whole fruit itself is bulky, heavy and thorny.

Although drying foods has received the most widespread and enthusiastic publicity in recent years as one of the well known preservation method, drying process is capable of affecting the nutritive value of food. Vitamin C can be destroyed by heat and air. Durian is a rich source of Vitamin C, containing over 19.7 to 23.2 mg/100 g (depends on variety). To minimize this problem, the drying operations must be carefuly designed to maintain the fruit's nutritional properties. There is also potential for "dry" durian products to be use in instant formulated drink, baby foods and for cost-less transportation. Transportation costs can be reduced significantly when shipping this product to distant market since the dry product result in less weight and more bulk can be transport to other places with less amount of shipping cost. The problem of the pungent smell which made it banned in public places and transportation can also be overcome when the fruit is dried.

1.3 Objectives

The objectiveof the research are

1) Produce durian powder by using spray dryer.
2) Study on the durian to water ratio of the feed, percentage of Maltodextrin needed to get the perfect product and the best temperature for drying of durian.
3) Identify the solubility of durian powder and the commercial value of produced durian powder

1.4 Scope

Literature shows very limited work on processing of Durian powder production. Lack of sufficient engineering and nutritional data for Durian processing emphasizes that more efforts need to be focused in these areas. Study on drying of durian is therefore started in undergraduate research work. In this study, nutrient level of Vitamin C of Durian puree at initial state and after powdered using spray drying in different temperature is investigated until the best and most amount is concluded.

The objective is to prepare Durian powder using spray drying method, evaluate the effects of drying on physico-chemical properties especially temperature effect on Vitamin C in Durian powder and determining the water to durian ratio to make the best product yield.

To achieve the objctives, scopes have been identified in this research. The scopes of this research are listed as below:-

1) Using local durians as the source of the feed
2) To preserve durian by spray drying (powdered)
3) Determine durian to water ratio
4) Determine Maltodextrin percentage which act as a carrier agent
5) Evaluate temperature effect when dried
6) To increase shelf life of durian
7) Commercial quality of the durian powder

CHAPTER 2

LITERATURE REVIEW

In this part, literature review of food material will be presented.

2.1 Food preservation

Food preservation is the process of treating and handling food to stop or greatly slow down spoilage (loss of quality, edibility or nutritive value) caused or accelerated by micro-organisms. Some methods, however, use benign bacteria, yeasts or fungi to add specific qualities and to preserve food (e.g., cheese, wine). Maintaining or creating nutritional value, texture and flavour is important in preserving its value as food. This is culturally dependent, as what qualifies as food fit for humans in one culture may not qualify in another culture.

Preservation usually involves preventing the growth of bacteria, fungi, and other micro-organisms, as well as retarding the oxidation of fats which cause rancidity. It also includes processes to inhibit natural ageing and discolouration that can occur during food preparation such as the enzymatic browning reaction in apples after they are cut. Some preservation methods require the food to be sealed after treatment to prevent recontamination with microbes; others, such as drying, allow food to be stored without any special containment for long periods.

Common methods of applying these processes include drying, spray drying, freeze drying, freezing, vacuum-packing, canning, preserving in syrup, sugar crystallisation, food irradiation, and adding preservatives or inert gases such as carbon dioxide. Other methods that not only help to preserve food, but also add flavour, include pickling, salting, smoking, preserving in syrup or alcohol, sugar crystallisation and curing.

2.2 Drying

Drying is a mass transfer process resulting in the removal of water or moisture from another solvent, by evaporation from a solid, semi-solid or liquid (hereafter product) to end in a solid state. To achieve this, there must be a source of heat, and a sink of the vapor thus produced.

The present invention is directed to a novel article of manufacture made from natural fruits and a novel process for the dehydration of fruits. More particularly, a novel, readily reconstitutable, free flowing flaked product having improved temperature stability, and shelf life properties produced naturally from fresh fruits and their mixtures.

Without being limited to the theory or mechanism stated, it is believed that by controlling the moisture content of the product, the formation of moisture related lumping, which is irreversible, is controlled. By controlling the ratio of the total sugar to insoluble solids and/or crude fiber content of the product, resistance to lumping caused by high temperature storage which may or may not be reversible, is controlled. Accordingly, the preferred embodiment controls lumping due to both moisture content and high temperature storage which is preferably controlled by drying , in an environment of cooling dehumidified air, a puree of specified composition (as set forth hereinbefore), and even more preferably, a puree containing added fruit skins and/or core materials. (Fuller Jr., John F., 1986)

2.2.1 Drying of solids

In the drying of solids, the desirable end product is in solid form. Thus, even though the solid is initially in solution, the problem of producing this solid in dry form is classed under this heading. Final moisture contents of dry solids are usually less than 10%, and in many instances, less than 1%.

The mechanism of the drying of solids is reasonably simple in concept. When drying is done with heated gases, in the most general case, a wet solid begins to dry as though the water were present alone without any solid, and hence evaporation proceeds as it would from a so-called free water surface, that is, as water standing in an open pan.

The period or stage of drying during this initial phase, therefore, is commonly referred to as the constant-rate period because evaporation occurs at a constant rate and is independent of the solid present. The presence of any dissolved salts will cause the evaporation rate to be less than that of pure water. Nevertheless, this lower rate can still be constant during the first stages of drying.

A fundamental theory of drying depends on a knowledge of the forces governing the flow of liquids inside solids. Attempts have been made to develop a general theory of drying on the basis that liquids move inside solids by a diffusional process. However, this is not true in all cases. In fact, only in a limited number of types of solids does true diffusion of liquids occur. In most cases, the internal flow mechanism results from a combination of forces which may include capillarity, internal pressure gradients caused by shrinkage, a vapor-liquid flow sequence caused by temperature gradients, diffusion, and osmosis. Because of the complexities of the internal flow mechanism, it has not been possible to evolve a generalized theory of drying applicable to all materials. Only in the drying of certain bulk objects such as wood, ceramics, and soap has a significant understanding of the internal mechanism been gained which permits control of product quality.

Most investigations of drying have been made from the so-called external viewpoint, wherein the effects of the external drying medium such as air velocity, humidity, temperature, and wet material shape and subdivision are studied with respect to their influence on the drying rate. The results of such investigations are usually presented as drying rate curves, and the natures of these curves are used to interpret the drying mechanism.

When materials are dried in contact with hot surfaces, termed indirect drying, the air humidity and air velocity may no longer be significant factors controlling the rate.

The “goodness” of the contact between the wet material and the heated surfaces, plus the surface temperature, will be controlling. This may involve agitation of the wet material in some cases.

Drying equipment for solids may be conveniently grouped into three classes on the basis of the method of transferring heat for evaporation. The first class is termed direct dryers; the second class, indirect dryers; and the third class, radiant heat dryers. Batch dryers are restricted to low capacities and long drying times. Most industrial drying operations are performed in continuous dryers. The large numbers of different types of dryers reflect the efforts to handle the larger numbers of wet materials in ways which result in the most efficient contacting with the drying medium. Thus, filter cakes, pastes, and similar materials, when preformed in small pieces, can be dried many times faster in continuous through-circulation dryers than in batch tray dryers. Similarly, materials which are sprayed to form small drops, as in spray drying, dry much faster than in through-circulation drying.

2.3 Drying methods

Drying is the oldest method of preserving food. The early American settlers dried foods such as corn, apple slices, currants, grapes, and meat. Compared with other methods, drying is quite simple. In fact, we may already have most of the equipment on hand. Dried foods keep well because the moisture content is so low that spoilage organisms cannot grow.

Drying will never replace canning and freezing because these methods do a better job of retaining the taste, appearance, and nutritive value of fresh food. But drying is an excellent way to preserve foods that can add variety to meals and provide delicious, nutritious snacks. One of the biggest advantages of dried foods is that they take much less storage space than canned or frozen foods.

Recommended methods for canning and freezing have been determined by research and widespread experience. Home drying, however, does not have firmly established procedures. Food can be dried several ways, for example, by the sun if the air is hot and dry enough, or in an oven or dryer if the climate is humid.

With the renewed interest in gardening and natural foods and because of the high cost of commercially dried products, drying foods at home is becoming popular again. Drying is not difficult, but it does take time and a lot of attention. Although there are different drying methods, the guidelines remain the same.

Although solar drying is a popular and very inexpensive method, Illinois does not have a suitable climate for it. Dependable solar dehydration of foods requires 3 to 5 consecutive days when the temperature is 95 degrees F, and the humidity is very low. The average relative humidity in central Illinois on days with 95 degrees F, temperatures is usually 86 percent. Solar drying is thus not feasible.

Drying food in the oven of a kitchen range, on the other hand, can be very expensive. In an electric oven, drying food has been found to be nine to twelve times as costly as canning it. Food dehydrators are less expensive to operate but are only useful for a few months of the year. A convection oven can be the most economical investment if the proper model is chosen. A convection oven that has a controllable temperature starting at 120 degrees F. and a continuous operation feature rather than a timer-controlled one will function quite well as a dehydrator during the gardening months. For the rest of the year it can be used as a tabletop oven.

2.4 General characteristic of dryers

Removal of water from solids is most often accomplished by contacting them with air of low humidity and elavated temperature. Less common, although locally important, drying processes apply heat radiactively of dielectricity in these operations as in freeze drying, the role of any gas supply is that of entrainer of the humidity.

The nature, size, and shape of the solids, the scale of the opeartion, the method of transporting the stock and contacting it with gas, the heating mode, are some of the many factors that have led to the devolepment of considerable variety of equipment.

2.5 Spray dryer

In the world of industrial dryers, there are a few types that accept pumpable fluids as feed material at the inlet end of the process and produce dry particulate at the outlet. Spray drying is unique in its ability to produce powders with a specific particle size and moisture content without regard for the capacity of the dryer and the heat sensitivity of the product. This flexibility makes spray drying the process of choice for many industrial drying operations.

2.5.1 Background of spray drying

Spray drying is presently one of the most exciting technologies for the pharmaceutical industry, being an ideal process where the end-product must comply with precise quality standards regarding particle size distribution, residual moisture/solvent content, bulk density and morphology.

One advantage of spray drying is the remarkable versatility of the technology, evident when analyzing the multiple applications and the wide range of products that can be obtained. From very fine particles for pulmonary delivery to big agglomerated powders for oral dosages, from amorphous to crystalline products and the potential for one-step formulations, spray drying offers multiple opportunities that no other single drying technology can claim.

2.5.2 Types of spray dryers

There are many types of spray dryers in our chemical environment such as co-current flow dryer, mix flow dryer and so on (Chiou, D., Langrish. T. A. G., Braham, R., 2008). A brief description of all the spray dryers exists in the current technology with explaination of it’s part in schematic diagram is given in coming pages

2.5.2.1 Co-current flow dryer

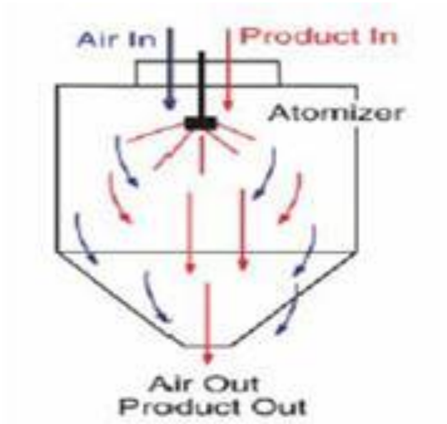

Figure 2.1

In the co-current flow dryer (Figure 2.1), the spray is directed into the hot air entering the dryer and both pass through the chamber in the same direction. Spray evaporation is rapid, and the temperature of the drying air is quickly reduced by the vaporization of water. The product does not suffer from heat degradation since once the moisture content reaches the target level, the temperature of the particle does not increase greatly because the surrounding air is now much cooler. Dairy and other heat-sensitive food products are preferably dried in co-current dryers.

2.5.2.2 Counter-current flow dryer

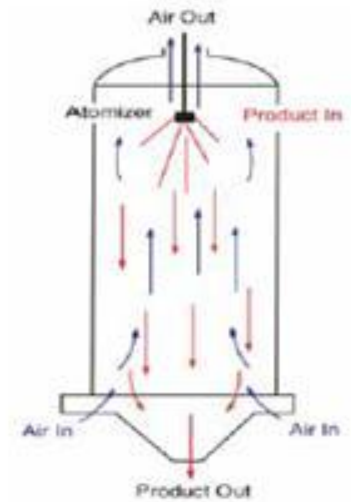

Figure 2.2

In this dryer design (figure 2.2), the spray and the air are introduced at opposite ends of the dryer, with the atomizer positioned at the top and the air entering at the bottom. A counter-current dryer offers more rapid evaporation and higher energy efficiency than a co-current design. Because the driest particles are in contact with hottest air, this design is not suitable for heat-sensitive products. Counter-current dryers normally use nozzles for atomization because the energy of the spray can be directed against the air movement. Soaps and detergents are commonly dried in counter-current dryers.

2.5.2.3 Mixed flow dryer

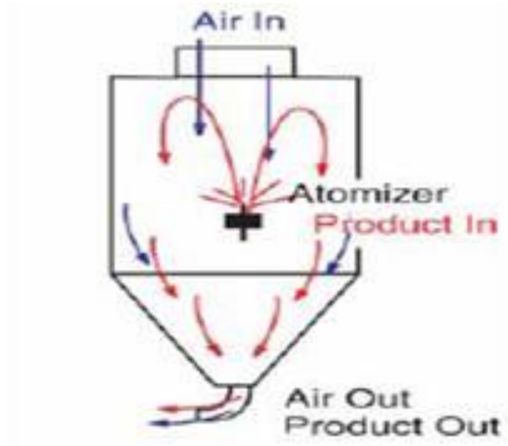

Figure 2.3

Dryers of this type combine both co-current and counter current flow. In a mixed flow dryer, the air enters at the top and the atomizer is located at the bottom. Like the counter-current design, a mixed flow dryer (figure 2.3) exposes the driest particles to the hottest air, so this design is not used with heat-sensitive products.

2.5.2.4 Open cycle dryer

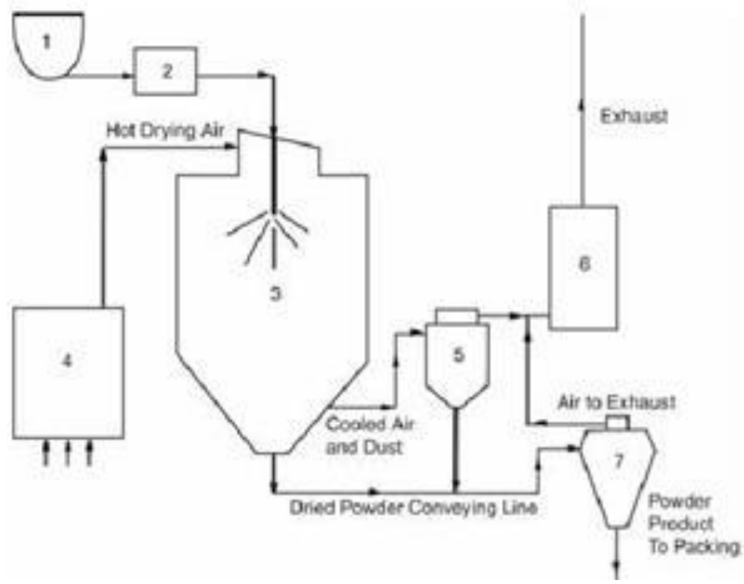

Figure 2.4

1) Feed storage
2) Pump
3) Drying chamber
4) Air heater
5) Cyclone
6) Gas scrubber
7) Separator

In an open cycle dryer (figure 2.4), drying air is drawn from the atmosphere, heated, conveyed through the chamber and then exhausted to the atmosphere. This is by far the most commonly used design.

2.5.2.5 Close cycle dryer

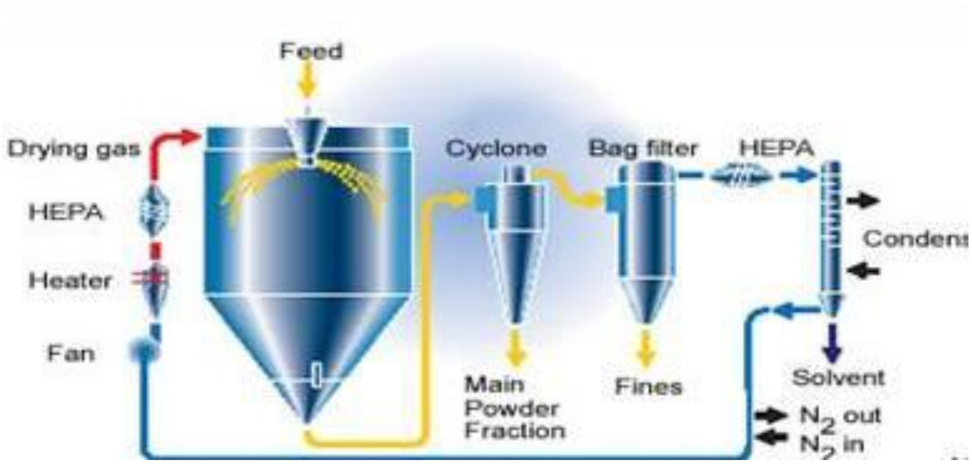

Figure 2.5

A closed cycle dryer (figure 2.5) recycles the drying gas, which may be air or more commonly, an inert gas such as nitrogen. Closed cycle units are the dryers of choice when:

1) Feedstock consists of solids mixed with flammable organic solvents.
2) Complete recovery of solvent is required.
3) The products are toxic
4) Pollution due to vapor, particulate emissions or odor is not permitted.
5) Explosion risks must be eliminated.
6) The powder will degrade by oxidation during drying.

2.5.2.6 Semi-closed cycle dryer

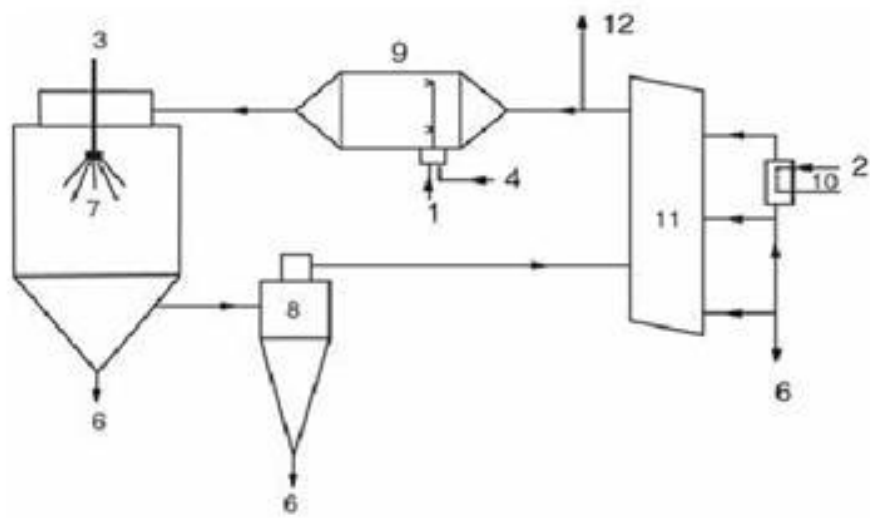

Figure 2.6

1) Combustion air
2) Coolant
3) Fedstock
4) Heater fuel
5) Condensed water discharged
6) Dried product
7) Drying chamber
8) Cyclone
9) Direct heater (gas)
10) Heat exchanger
11) Scrubber/condenser
12) Air bleed to atmosphere

This dryer design (figure 2.6) is a cross between open and closed cycle dryers. A direct-fired heater is used and the air entering the system is limited to that required for combustion. An amount of air equal to the combustion air is bled from the system at the other end of the process. The gas (mainly products of combustion) is recycled through the dryer. The recycled gas has very low oxygen content, making it suitable for materials that cannot be exposed to oxygen, due to explosive hazard or product degradation.

2.5.2.7 Single stage dryer

In a single stage dryer, the moisture is reduced to the target (typically 2-5% by weight) in one pass through the dryer. The single stage dryer is used in the majority of designs.

2.5.2.8 Two stage dryer

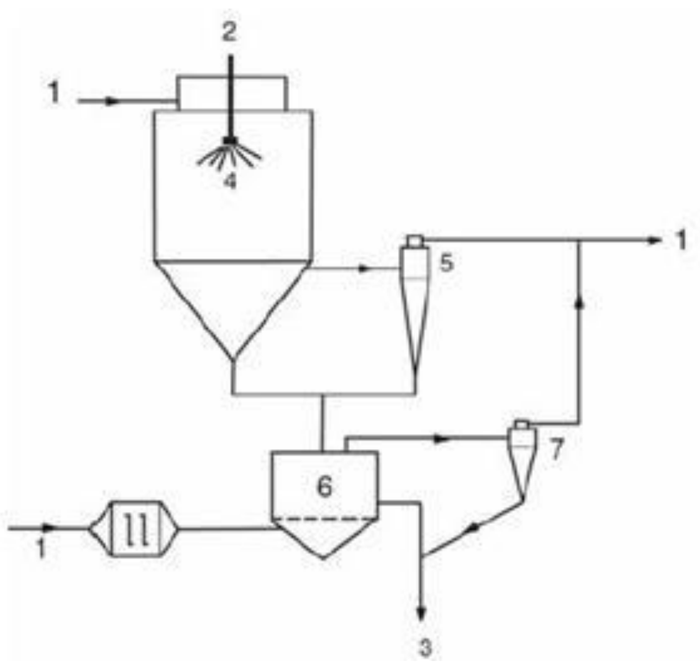

Figure 2.7

1) Air	5) Cyclone
2) Feedstock	6) Stationary fluid bed
3) Dried product	7) Fluid bed cyclone
4) Drying chamber	8) Transport cyclone

In a two stage dryer (figure 2.7), the moisture content of product leaving the chamber is higher (5-10%) than for the final product. After leaving the chamber, the moisture content is further reduced during a second stage. Second stage drying may be done in a fluidized bed dryer or a vibrating bed dryer. Two stage dryers allow the use of lower temperatures in the dryer, making the design a good choice for products that are particularly heat sensitive.

2.5.2.9 Vertical dryer

The chamber of a vertical (tower) dryer has the form of a tall cylinder with a cone-shaped bottom. Spray nozzles may be located at the top (co-current flow) or bottom (counter-current or mixed flow) of the chamber. Inlets for the drying air may be located at the top, bottom or side of the chamber. Vertical spray dryers are usually large and the residence time of sprayed particles is relatively long, allowing the use of higher flow nozzles such as the TD, which produce relatively large particles.

2.5.2.10 Horizontal dryer

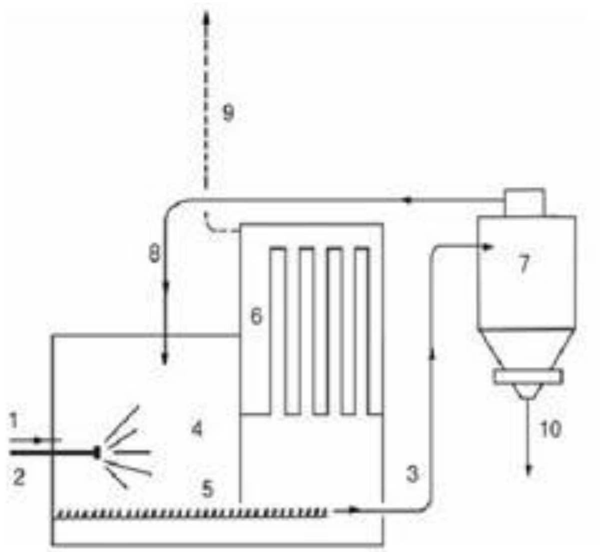

Figure 2.8

1) Drying air
2) Feedstock
3) Pneumatic conveyor
4) Drying chamber
5) Powder conveyor
6) Filter bags
7) Cyclone
8) Dust return
9) Exhaust to atmosphere
10) Dried powder

The chamber of a horizontal dryer (figure 2.8) has the form of a rectangular box with either a flat or a "V" shaped bottom. Nozzles in a box dryer normally spray horizontally, with the dried particles falling to the floor, where they are removed to a bagging area by a sweep conveyor or screw conveyor. Box dryers are usually small and the particle residence time relatively short, requiring the use of low flow nozzles, which produce relatively small particles

2.6 Advantages of spray drying

1) Able to operate in applications that range from aseptic pharmaceutical processing to ceramic powder production
2) The dry particle size can be easily controlled by atomization of the liquid feed and the design of the hot gas inlet. The correct spray dryer design and atomization technique can increase yields for products that require classification. Spray dryers can typically produce between 30 to 500 micron average particle size, in a bell shaped distribution
3) The shape of most spray dried particles is spherical, which provides for fluid-like flow properties. This makes many downstream operations (e.g. packaging, pressing, filtering, handling) easier and less costly.
4) The heat and mass transfer during drying occurs in the air and vapor films surrounding the droplet. This protective envelope of vapor keeps the particle at the saturation temperature. As long as the particle does not become "bone-dry", evaporation is still taking place and the temperature of the solids will not approach the dryer outlet temperature. This is why many heat sensitive products can be spray dried easily at relatively high inlet temperatures.
5) The surface area produced by atomization of the liquid feed enables a short gas residence time, ranging from 3-40 seconds depending upon the application, which permits spray drying without thermal degradation. This allows for fast turn-around times and product changes because there is no product hold up in the spray drying equipment.
6) Because a spray dryer is a gas suspended process, the dryer chamber remains dry by design. Therefore, many corrosive materials can be processed with carbon steel as the primary material of construction of the spray dryer chamber, which reduces capital costs.
7) Spray drying produces the most homogeneous product for multi-component solution/slurries. Each particle will be of the same chemical composition as the mixed feed.

2.7 Spray drying basics

2.7.1 Concentration

Feedstock is normally concentrated prior to introduction into the spray dryer. The concentration stage increases the solids content thereby reducing the amount of liquid that must be evaporated in the spray dryer.

2.7.2 Atomization

The aim of atomizing the concentrate is to provide a very large surface, from which the evaporation can take place. The smaller droplets, the bigger surface, the easier evaporation, and a better thermal efficiency of the dryer are obtained. The ideal from a drying point of view would be a spray of drops of same size, which would mean that the drying time for all particles would be the same for obtaining equal moisture content.

Over the years several researches have studied the mechanism by which atomization takes place and several theories have evolved. The most widely accepted are based on the liquid jet theory (Lord Rayleigh, 1878). A liquid stream accelerated by the force of gravity is pulled apart or disintegrated into teardrop-shaped droplets. The surface tension of the liquid causes the droplet, suspended in air, to form itself into a sphere.

2.7.3 Droplet air contact

Once the liquid is atomized it must be brought into intimate contact with the heated gas for evaporation to take place equally from the surface of all droplets within the drying chamber. The heated gas is introduced into the chamber by an air disperser, which ensures that the gas flows equally to all parts of the chamber.

2.7.4 Droplet drying

The largest and most obvious part of a spray-drying system is the drying chamber. This vessel can be taller and slander or have large diameter with a short cylinder height. Selecting these dimensions is based on two process criteria that must be met. First, the vessel must be of adequate volume to provide enough contact time between the atomized cloud and the heated glass.

The second criterion is that all droplets must be sufficiently dried before they contact a surface. This is where the vessel shape comes into play. Centrifugal atomizer requires larger diameter and less cylinder height. Nozzles are just the opposite. Most spray dryer manufacturers can estimate, a given powder’s mean particle size, what dimensions are needed to prevent wet deposits on the drying chamber walls.

Drying chambers are usually constructed of stainless steel sheet metal, with stiffeners for structural support and vessel integrity. Sheet steel finish and weld polish can be specified to meet any requirement. Insulation is usually applied to the outside of the vessel, and stainless steel wrapping is seam-welded over the entire vessel. This provides a thermally efficient and safe system that is easy to clean has no crevice areas that might become contaminated.

2.7.5 Separation

In almost every case, spray-drying chambers have cone bottoms to facilitate the collection of the dried powder. When the coarse powder is to be collected, they are usually discharged directly from the bottom of the cone through a suitable airlock, such as a rotary valve. The gas stream, now cool and containing all the evaporate moisture, is drawn from the center of the cone above the cone bottom and discharge through a side outlet. In effect, the chamber bottom is acting as a cyclone separator. Because of the relatively low efficiently of collection, some fines are always carried with the gas stream. This must be separated in high-efficiency cyclones, followed by a wet scrubber or in a fabric filter (bag collector). Fines are collected in the dry state (bag collector) are often added to the larger powder stream or recycled.

2.7.6 Spray dryer used

In this research we use lab SD-06 Laboratory Scale Spray dryer. The details of the equipment are given in the table below.

Table 2.1: Details of spray dryer

SD-06 Laboratory Scale Spray Dryer	
Intoduction	The Lab-Plant SD-06 Laboratory Scale Spray Dryer is the result of 30 years of continuous development in the field of laboratory scale spray drying systems. The unit is self contained and supplied complete and ready for immediate operation. All major components are housed within a stainless steel cabinet and the unit can be used on a bench top or with an optional stainless steel stand. The SD-06 only requires connection to a 13 amp, 220/240 V, 50 Hz power supply (Other Power Requirements Available) and provision for exhausting the evaporated moisture to atmosphere or to an existing extraction system.
Technique	A menu driven microprocessor controller allows the selection of inlet temperature, airflow, automatic de-blocker frequency and pump speed. The controller features an RS 232 output for connection to a PC or datalogger and software allows the control and monitoring of all functions and printing of results. The self-priming peristaltic pump delivers the sample liquid from a container through a small diameter jet into the main chamber. At the same time an integral compressor pumps air into the outer tube of the jet which causes the liquid to emerge as a fine atomised spray into the drying chamber. Heated air is blown through the main chamber evaporating the liquid content of the atomised spray. The solid particles of the material, which are normally in a free flowing state, are then separated from the exhaust air flow by a cyclone and collected in the sample collection bottle. The exhaust airflow is directed through a flexible 50 mm diameter hose direct to atmosphere or to an existing extraction system.
Applications	Spray drying can be used in a wide range of applications where the production of a free-flowing powder sample is required. This technique has successfully processed materials in the following areas: 1) Beverages 2) Flavours and Colourings

	3) Milk and Egg Products 4) Plant and Vegetable Extracts 5) Pharmaceuticals 6) Heat Sensitive Materials 7) Plastics 8) Polymers and Resins 9) Perfumes 10) Ceramics and Advanced Materials 11) Soaps and Detergents 12) Blood 13) Dyestuffs 14) Foodstuffs 15) Adhesives 16) Oxide 17) Textiles 18) Bones 19) Teeth and Tooth Amalgam Most solutions and suspensions can be spray dried providing that the resulting product has the characteristics of a solid material.

CHAPTER 3

METHODOLOGY

In this part, methodology of spray drying durian will be presented.

3.1 Introduction

For this research the type of method that is used is experimental method. Drying process is the main process to convert durian powder from durian juice. There are three major parts in this experiment. First, drying process of durian using spray dryer in different durian to water ratio, various maltodextrin percentage and different set temperature and secondly the measurement of solubility of produced powder, using the method of centrifugation and finally doing sensory evaluation on the produced juice.

The main part of this research is to prepare durian powder from durian puree while preserving its best quality.

3.2 Material

Material that will be used in this research project is durian puree.

3.2.1 Durian fruit

The durian fruit firstly are bought from the the stalls nearby. After that the arils and seeds are removed from the thorny husks. It was then placed in a plastic container before it is placed in a freezer.

Figure 3.1: Durian fruit in the freezer

3.2.2 Maltodextrin

Maltodextrin is a polysaccharide that is used as a food additive. It is produced from starch by partial hydrolysis and is usually found as a creamy-white hygroscopic spray dried powder. Maltodextrin is easily digestible, being absorbed as rapidly as glucose, and might be either moderately sweet or almost flavorless. It is commonly used for the production of natural sodas

Maltodextrin can be enzymatically derived from any starch. In the US, this starch is usually corn; in Europe, it is commonly wheat. While wheat-derived maltodextrin may cause concern for celiacs that it may contain gluten, maltodextrin is such a highly processed ingredient that the protein is removed, rendering it gluten free.

If wheat is used to make maltodextrin, it will appear on the label. Even so, the maltodextrin will be gluten free.

Table 3.1: Specification of Maltodextrin 10

Specification	
Dextrose equivalent	9 - 12
Moisture, %	Max. 5.0
pH (20% solution)	4.5 - 5.5
Sulphur dioxide	Max. 10
Color (O. D.)	Max. 2.0
Bulk density (tapped), g/L	450 - 600
Shelf life	2 years
Durian	Tapioca starch
Storage condition	Cool & dry condition

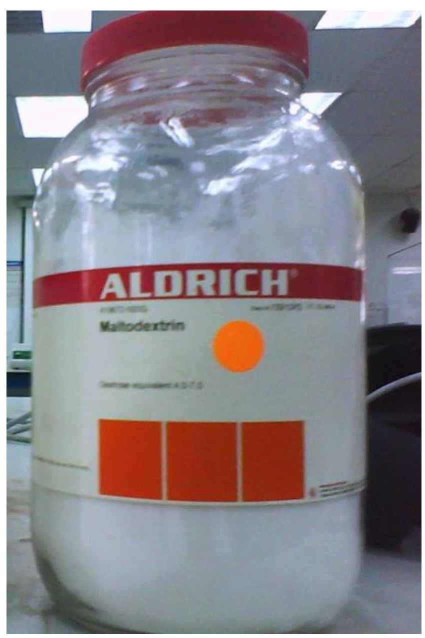

Figure 3.2: Maltodextrin

In this process different amount of maltodextrin is added to durian puree everytime the experiment was carried out (Table 3.1). This is to determine the best amount of maltodextrin that should be added in order to preserve the best texture, color and the taste of the powder. For every run of experiment, 300 mL of durian juice is prepared. Then, maltodextrin is weighed using the weighing machine in lab and slowly added to durian juice while the juice is being stirred using magnetic stirrer until it is well mixed.

Table 3.2: Percentage of maltodextrin in 300mL durin juice

Experiment	Durian juice, mL	Maltodextrin percentage added to 300 mLdurian juice , %	Maltodextrin, g
1	300	30	10
2	300	45	15
3	300	60	20
4	300	75	25
5	300	90	30

Figure 3.3: Different maltodextrin percentage

3.2.3 Anti-Caking Agent

An anticaking agent is an additive placed in powdered or granulated materials, such as table salt, to prevent the formation of lumps, making the product better for packaging, transport, and for the consumer.

An anticaking agent in salt is denoted in the ingredients, for example, as "anti-caking agent (554)", which is sodium aluminosilicate, a man-made product. This product is present in many commercial table salts as well as dried milks, egg mixes, sugar products, and flours. In Europe, sodium ferrocyanide (535) and potassium ferrocyanide (536) are more common anticaking agents in table salt. Natural anticaking agents used in more expensive table salt include calcium carbonate and magnesium carbonate.

Some anticaking agents are soluble in water; others are soluble in alcohols or other organic solvents. They function either by adsorbing excess moisture, or by coating particles and making them water repellent. Calcium silicate ($CaSiO_3$), a commonly used anti-caking agent, added to e.g. table salt, adsorbs both water and oil.

Anticaking agents are also used in non-food items such as road salt, fertilisers, cosmetics, synthetic detergents, and in manufacturing applications.

Table 3.3: Anti-caking agent and it's amount for common food stuff by Ministry of Health and Welfare

Food stuff	Anti-caking agent	Conditions and limit (mg/kg)
Meat tenderizer	Calcium Stearate, Silicon Dioxide, Amorphous	10000 *GMP
Milk powder	AluminiumSilicate, Calcium Carbonate, Calcium Silicate, Calcium Phosphate, Magnesium Oxide, Magnesium Phosphate, Silicon dioxide, Amorphous	10000
Salt (sodium chloride)	Aluminium Stearate, Calcium Stearate, Magnesium Oxide, Magnesium Silicate	20000
Salt substitute	Calcium Silicate, Silicon Dioxide, Amorphous	10000
Soft drink, powdered	Calcium Carbonate, Calcium Phosphate, Tribasic Silicon Dioxide, Magnesium Carbonate	5000, 10000, 15000 *GMP
Soups and sauces, powdered	Silicon Dioxide, Amorphous, Sodium Silico-aluminate, Calcium Carbonate, Magnesium Carbonate	10000 *GMP

3.2.3.1 Calcium Carbonate

Calcium carbonate is a chemical compound with the chemical formula $CaCO_3$. It is a common substance found in rock in all parts of the world, and is the main component of shells of marine organisms, snails, pearls, and eggshells. Calcium carbonate is the active ingredient in agricultural lime, and is usually the principal cause of hard water. It is commonly used medicinally as a calcium supplement or as an antacid, but excessive consumption can be hazardous.

Calcium carbonate added to finely powdered or crystalline food products to prevent anti-caking, lumping or agglomeration. The specification of the anti-caking agent (calcium carbonate) is shown below.

Table 3.4: Specification of Calcium Carbonate

Specification of Calcium Carbonate	
Cas Number	471-34-1
Molar Mass	100.09 g/mol
Appearance	White powder
Density	2.71 g/cm^3 (calcite) 2.83 g/cm^3 (aragonite)
Solubility in water	0.00015 mol/L (25°C)

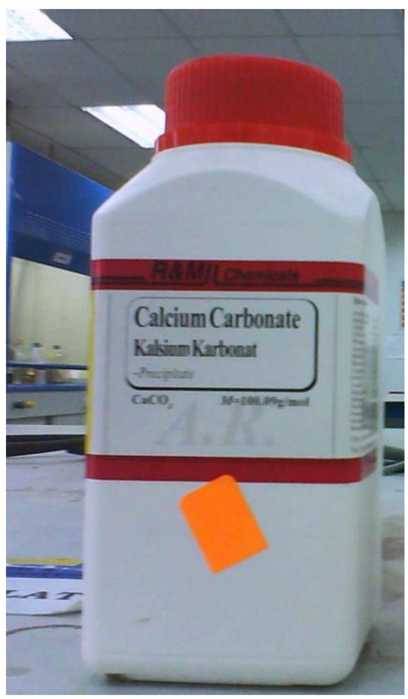

Figure 3.4: Calcium carbonate

3.3 Equipment

Equipment that will be use in this undergraduate researched project is spray dryer.

3.3.1 Spray dryer

The lab scale spray dryer model of SD-06 is the main equipment used in this study.

Table 3.5: Specification of spray dryer

Specification of spray dryer	
Type/Brand	Lab Plant SD 06
Capacity	50 – 200 g/hr
Vacuum pressure	1 psig
Serial No.	399
Manufacturing Code	2504

Figure 3.5: Spray dryer

3.4 Experiment Flow Chart

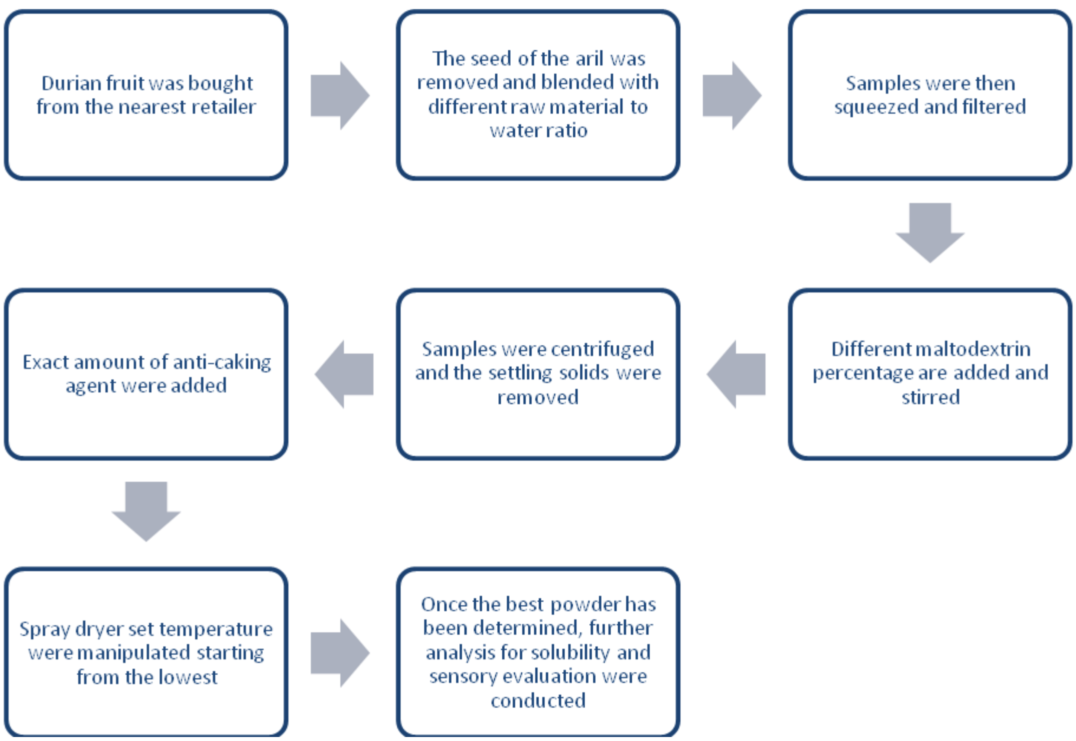

Figure 3.6: Schematic diagram for the process to convert durian fruit to durian powder

3.5 Method of research

Method of research are sample preparation, drying process and analytical experiment.

3.5.1 Sample preparation

The fresh flesh samples for this part of experiment is removed from the durian skin and the seed is discarded. The flesh is made into a puree by blending it with different durian to water ratio until smooth. The puree are then squeezed and filtered before different maltodextrin percentage is added to the durian juice. Fine granulated sugar (maltodextrin) is added to improve retention of colour and flavour and to improve drying characteristics of the final product (Askar et al. 1992). Later the samples must be centrifuged to remove any suspended solids in the solution. Anti caking agent is added later to the durian juice with the exact amount and homogenized. Selection of fully ripe is by shaking the fruit and listening for the sound of the seeds moving within is essential for preventing suspended solid during blending process and to get optimal amount of juice out of it.

Figure 3.7: Removing seed, blending, squeezing and filtering.

Figure 3.8: Centrifugationof samples

3.5.2 Drying process

A 300 mL batch of puree that has been prepared is now ready for spray drying. The pump tube will be placed in the durian sample. The main switch will be switched on. Then, the fan, compressor and the heater will be switched on using the apprpriate screen and start button. The fan settings will be set to maximum (50). When the air flow at maximum setting, the set temp screen will be used to set the temperature required (100-200°C). This will be varied. The actual inlet and outlet temperature will be displayed at all time one the set temperature screen. The pump will be set to a slow rate (5-10). When samples reaches the jet the spray drying operation should commence and dried powder should be observed spiraling down the cyclone into the collection bottle. The main power switch and power supply will be switched off. The sample weight will be recorded.

3.5.3 Analytical experiment

Analytical experiement that was done is the solubility analysis and sensory evaluation

3.5.3.1 Solubility Analysis

Solubility will be determined according to the Eastman and Moore method (1984) and modified by Cano-Chauca, Stringheta, Ramos and Cal-Vidal (2005). According to the method 1 g of powder will be added to the 100 mL distilled water and mixed at high velocity using the aid of stirrer for 5 minutes. Later the solution will be placed in a centrifuge tube and centrifuged at 2600 rpm for 5 minutes. 25 mL of the centrifuged supernatant will be placed in a previously weighed Petri dish and immediately oven dried at 105 °C for 5 hours. Solubility percentage is calculated by weight difference of the solid retained in the solution and mass of the powder added.

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

3.5.3.2 Sensory Evaluation

Sensory evaluation will be the final part in this research. This will identify the commercial value of produced durian powder. The evaluation will be done by random probability. The important criteria of the powder which should be evaluated will be determined and a sensory evaluation form will be constructed. From the Sensory Evaluation Manual by Associate Professor Richard Mason from The University of Queensland, the sensory evaluation criteria will be determined. The criteria will be divided into three parts which are appearance, texture and flavours. The sensory evaluation will be conducted randomly at Universiti Malaysia Pahang KK1 cafeteria. The durian powder and the reconstituted juice will be given to the people at cafeteria and asked to evaluate the product according to criteria stated in the evaluation form. 10 people will be selected and evaluation is conducted. All the results will be collected for further analysis.

CHAPTER 4

RESULT AND DISCUSSIONS

In this part, result and discussions of spray dried durian powder will be presented.

4.1 Spray Drying

By using spray dryer, three major analysis were done. The first one is the durian to water ratio, second is the change in the amount of maltodextrin and thirdly on the various temperatures. The other parameters were kept constant during this analysis. The analysis was done based on the product which is the amount of durian powder produced and it's characteristics.

4.1.1 Change in durian to water ratio

One of the objective of this experiment is to determine the suitable durian to water ratio for the feed sample. By using spray dryer to convert durian juice to powder, all the parameters or condition in the operation have been kept constant except for the durian to water ratio. The first sets of experiments were done to find the suitable durian to water ratio for sample feed. In this case the temperature was kept constant at 170°C. The condition and result are given in the below this page.

Table 4.1: Condition in spray dryer using various durian to water ratio

Run	Juice, mL	Durian to water ratio	T_I, °C	T_o, °C	Fan setting	Pump setting	De-blocker
1	300	1:5	170	100	20	7	Fast
2	300	1:4	170	100	20	7	Fast
3	300	1:3	170	100	20	7	Fast
4	300	1:2	170	100	20	7	Fast
5	300	1:1	170	100	20	7	Fast

Table 4.2: Net weight of durian powder for various durian to water ratio

Run	Durian juice, mL	Durian to water ratio	Net weight of durian powder, g
1	300	1:5	1.9
2	300	1:4	2.2
3	300	1:3	2.5
4	300	1:2	2.8
5	300	1:1	6.4

In this research of different durian to water ratio, the prediction of durian powder amount which will be produced, is the challenge of the study. This is because lower ratio makes it difficult to squeeze the juice out and also makes the juice thicker and more suspended solids can be obserned with the naked eye. This will eventually cloged the jest atomizer of the spray dryer. This can be overcome by centrifuging it to remove the suspended solids and make the sample purer with its juice. As we know, lower ratio gives the sample more purity.and thus increase the yield product. Water act as a medium for squeezing the durian juice out. So, the less water is added to durian, the more yield of product will be obatined. Since we are trying to commercialized the powder, the yiled amount is very essential to obtained profits. A graph is plotted for the product yield versus durian to water ratio

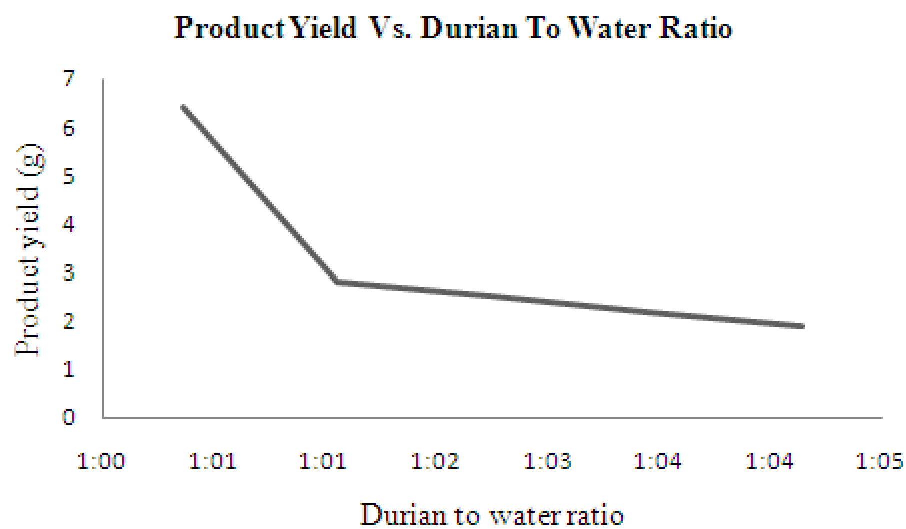

Figure 4.1: Product yield versus water to durian ratio

Though we know that the durian powder increase with the lower durian to water ratio prepared, we need to choose the best suitable durian to water ratio for the durian powder. From the test, 1:1 of raw mterial to water ratio is found to be the best. 1:5 and 1:4 of durian to water ratio were found that very little product was yield. Due to commercial value and high amount of yield, 1:1 of durian to water ratio were chose as the best suited in durian juice. The feed is also the same as the durian used.

4.1.2 Change in maltodextrin

The other objective of this experiement is to determine the suitable amount of maltodextrinto be added in 300 mL of durian juice. By using spray dryer to convert durian juice to powder, all the parameters or conditions in the operation have been kept constant except for the amount of maltodextrin added. 1:1 durian to water ratio are used. The second sets of experiments were done to find the suitable amount of maltodextrin for 300 mL of durian juice. In this case the temperature was kept constant at 170°C. The result are given below this page.

. **Table 4.3:** Net weight of durian powder for various amount of maltodextrin

Run	Durian juice, mL	Maltodextrin percentage added to 300mLdurian juice, %	Net weight of durian powder, g
1	300	10	6.4
2	300	15	7.3
3	300	20	7.8
4	300	25	8.9
5	300	30	9.7

After getting the result it has clearly known that increase the amount of maltodextrin will yield more powder. A graph is plotted for the percentage of maltodextrin versus amount of powder yield. This is because the amount of maltodextrin is what we producing as the powder in the end, the more the amount of maltodextrin we add the more durian powder we get. The texture of powder become more fine with the increase of maltodextrin. Compare to less amount of maltodetrin, carrying the taste of durian juice, more maltodextrin has the capacity to carry more taste yet remain as more fine particle. The color of durian powder turns from yellow to white or become more pale with the increase of maltodextrin. The original color of the maltodextrin is pure white so the more we add the amount of maltodextrin the more will the effect of its color on the produced durian powder. The odor also become less strong when the more maltodextrin is added.

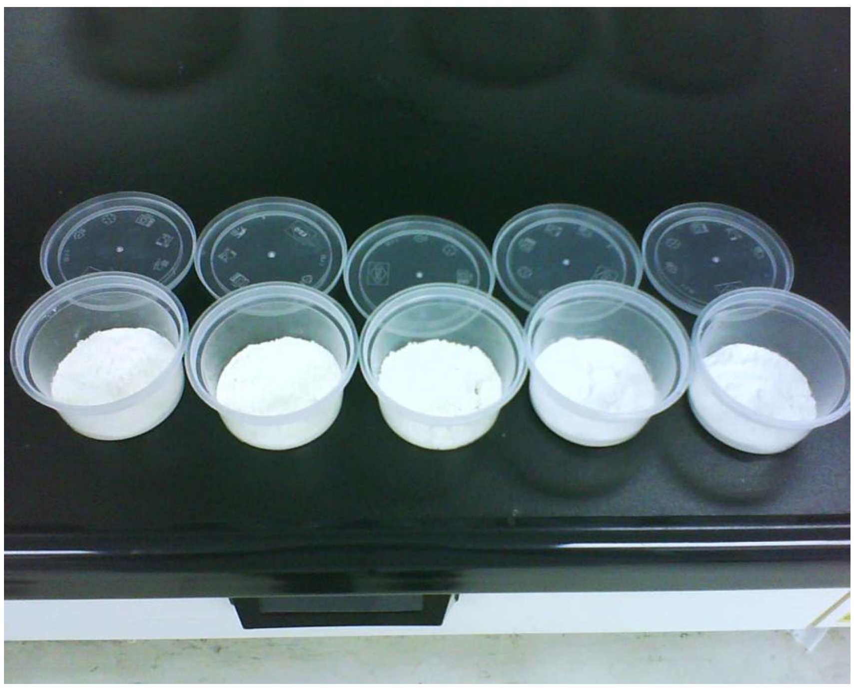

Figure 4.2: Durian powder arranged in the increase amount of maltodextrin from the left to the right

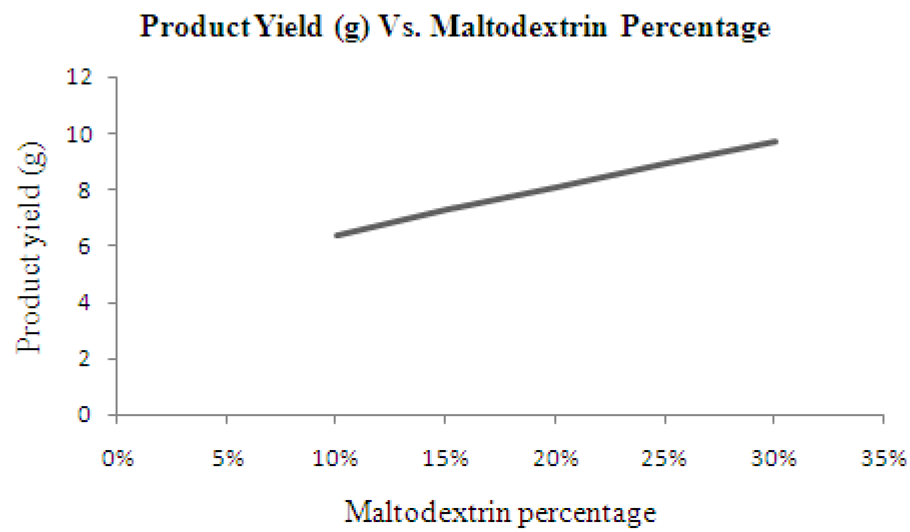

Figure 4.3: Product yield versus maltodextrin percentage

Though we know that the amount of durian powder increase with the amount of maltodextrin added, we need to choose the best suitable amount of maltodextrin for the durian drink. From the analysis of taste, odor and color, 10% of maltodextrin is found to be the best amount to add in durian juice. 25% and 30% of maltodextrin were found hard to dissolve in the durian juice. The color of this reconstituted juice gave pale yellow and the odor is not so strong, where else 10% and 15% of maltodextrin exists to be a little more hygroscopic and viscous. The amount of powder produced we also very little compare to 30% of maltodextrin. Due to commercial value and high amount of yield, 10% of maltodextrin were chose as the best suited amount to be added in durian juice.

4.1.3 Change in temperature

The last objective of this experiment is to find the best temperturefor commercial durian juice production by lab scale spray dryer. In this experiment all the other parameter are kept constant. 1:1 durian to water ratio and 10% of maltodextrin were used to make the feed sample as it has been found to be the best suited for the feed. The result of this experiemnt are given inte below page.

Table 4.4: Net weight of durian powder for different amount of temperature

Run	Durian juice, mL	Set temperature, °C	Net weight of powder, g
1	300	160	0.0
2	300	170	6.4
3	300	180	5.9
4	300	190	5.1
5	300	200	4.7

There was no significance difference between the powder produced using temperatures of 170°C, 180°C and 190°C in terms of physical look, odor, taste and even the amount produced. This proves that the temperature does not affect much on all these characters. The amount of produced powder in this three different temperature are almost the same. This also shows that the moisture contnet of all produced powder is almost same, though different temperature is beingapplied.

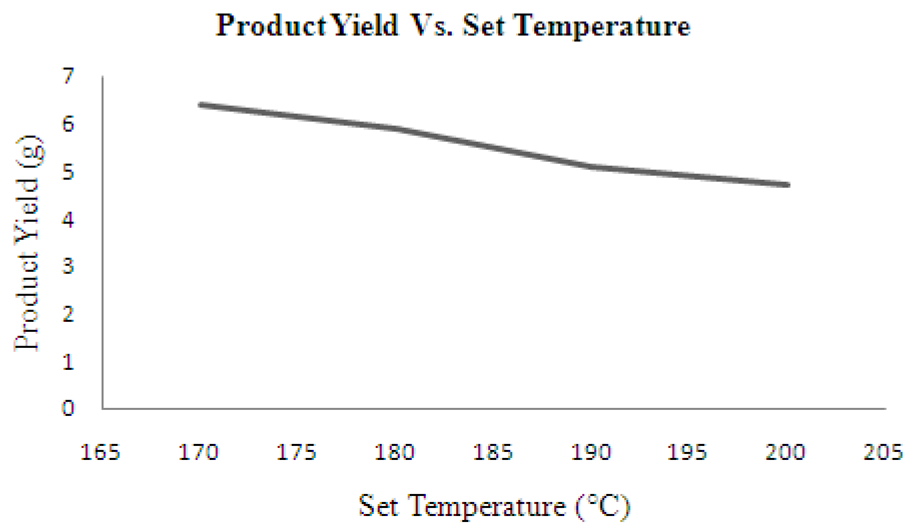

Figure 4.4: Product yield versus set temperature

At temperature of 160°C, no pwders were produced. This is because the heat is not sufficientto dry the durian juice. At 200°C only 4.7 g of powders produced. This is because at 200°C most of the powders were burnt. This temperature is simply too high for the production of durian powder using lab scale spray dryer. Minimum 170°C is needed to convert the durian juice to powder. The powder produced in 170°C looks fine and has a good aroma of durian. Though there were no significant differences among all the powders produced in various temperatures, 170°C chosen as the best temperature for drying durian juice. This is becauseas we know nutrient lost is proportional to temperature, so to prevent nutrient lost from durian juice we took the minimum temperature as the best.

4.2 Analytical experiment

Analytical experiemnt were done on the produced durian powder. Once the best parameter on the durian to water ratio, maltodextrin percentage and temperature has been chosen, the powder is further analyzed. In the analytical experiment, the solubility and sensory evaluation were done.

4.2.1 Solubility analysis

Solubility analysis is conducted for the durian powder produced using the best parameter on the durian to water ratio, maltodextrin percentage and temperature. As we know maltodextrin itself is highly soluble. Increasing the amount of maltodextrin should increase the solubility.The solubility analysis is conducted to evaluate the ability of the powder to dissolve in the water. This analysis was found essential in order to produce ready to dissolve powder. This analysis was conducted in Universiti Malaysia Pahang laboratory using the centrifugation equipment. The results of the solubility analysis are illustrated in the following table

Table 4.5: Result of solubility analysis

Weight of boat	Weight of boat + weight of supernatant after drying	Weight of solid retained after drying	Percentage of solubility
1.288 g	1.477 g	0.189 g	75.6 %

Solubility problems occur when foods are submitted to high temperatures, and especially in products with high concentration of solids. Maltodextrin is one carrier that is most used in process of spray drying due to its physical properties, such as high solubility in water. However, durian properties itself had different result to the system. There was a change in the microstructure and influencing its functional solubility property. Instant powder solubility is directly related to its microstructure. The characteristics of particles of powdered durian juice change in function of maltodextrin addition. According to (Gombas et al. 2003), crystalline and amorphous forms present differences on the size and shape of the particles, chemical properties, chemical stability, solubility in water, and hygroscopicity. This means that addition of maltodextrin addition had some effect on the solubility of durian powder. Those research results are in agreement with (Yu et al. 2001), who reports that amorphous solids possess high solubility and high velocity of dissolution as compared to the crystalline state.

4.2.2 Sensory evaluation

Sensory evaluation is another major part in this experiment. Once the best parameter of producing durian powder has been chosen, this sensory evaluation was done on the powder solution. This evaluation was divided into three main criteria, which are appearance, flavor and the texture. In the appearance section, color, size and the shape of the powder was analyzed. In the flavor section, odor and taste were analyzied. In the section of texture, viscosity and mouth feel were analyzed. All these categories were analyzed from the scale of very poor, poor, uncertain, good, to very good. This sensory evaluation was done among the student of Universiti Malaysia Pahang. This survey was taken place in the cafeteria. 10 students were randomly chose and given explaination on the research done. They were briefed about the criteria of analysis as well. The students were given the form of analysis and a little amount of reconstituted durian juice to taste. The sample powder was also shown to them to be analyzed. The results from the random sensory evaluation were collected and allthe resultas are illustrated in the table given.

Table 4.6: Result of sensory evaluation

Criteria		**Score Frequency**				
		Very poor	**Poor**	**Uncertain**	**Good**	**Very good**
Appearance	**Color**			2	8	
	Size			1	9	
	Shape				10	
Flavor	**Odor**				6	4
	Taste			1	9	
Texture	**Mouth feel**				4	6
	Viscosity				10	
Total				4	56	10

When the survey from students were analyzed, most of them has given good response for the taste of the juice. Only the color were given less marks. This is because the color is not very yellow may be due to storage process. Overall this survey shows that the produced durian powder has a very good commercial value and it will have very good potential in the market. The color can be added synthetically if this product is happened to be marketed to increase the commercial value.

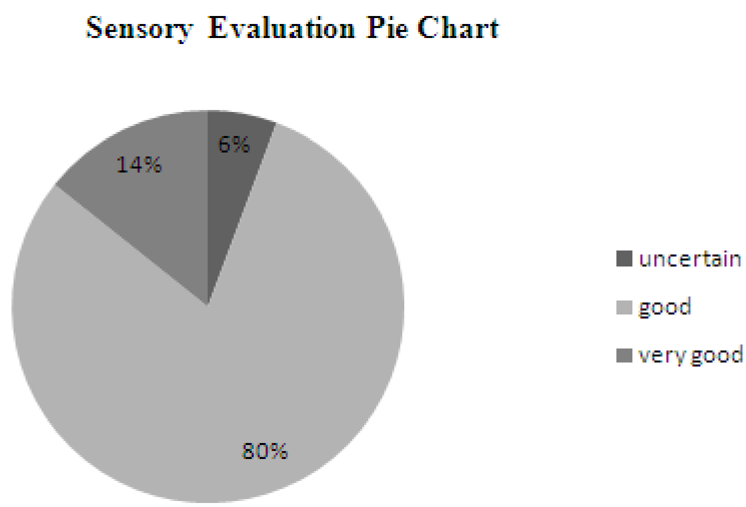

Figure 4.5: Pie chart for sensory evaluation

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

In this part, conclusion and recommendations of spray drying durian will be presented.

5.1 Conclusion

In this chapter, the chosen final parameters for all the variables are discussed. Justification for choosing such parameters are also given. The effect of every variable are also elaborated in detail. The study on the title of "Spray Dried Durian Powder" has been successfully done. From the result obtained and analysis conducted, it can be concluded that the purpose of this study has been achieved. This study is to produce durian powders using spray dryer and to identify the best condition of drying process in producing durian powders.

The durian juice was chosen in this research due to its important potential for the international market. The durian has a great potential for exportation and it is able to compete in the international market, either as puree, juice or mixtures with other juices. Many active compounds and chemicals have been found in durian, as scientists have been studying its properties since the 1940s.

The fruit pulp industry has become one of the world's biggest agrobusiness. Even though exporter of concentrated fruit juices have a variety of benefits, but alternative processing and preservation techniques should be explored in order to increase the benefits that all ready have. In order to meet the demand, preservation by means of drying is chosen. The main purpose of drying is to allow longer periods of storage, to minimize packaging requirements and to reduce shipping weight. At the same time, powders that obtained by drying concentrated fruit juices or pulps could represent interesting commodities, since this kind of dried product would provide a stable, natural ingredient that could be easily manipulated and used in formulated foods. The results of this study indicated addition of maltodextrin reduced the stickiness of the products and altered the physical properties of the spray-dried powders.

The results showed that inlet air temperature has great influence on the physical properties of the spray-dried powders. As inlet air temperature increased, the yield of the powder decreased. Inlet air temperature showed significant effect on all the responses studied. Increasing temperature led to higher process yield and powder hygroscopicity. Maltodextrin addition had negative effect on powder hygroscopicity, confirming its efficiency as a carrier agent. The increase on this variable also caused a reduction on process yield, probably due to the increase on feed viscosity. In respect to powder morphology, increasing temperatures resulted in a greater number of particles with smooth surface and with larger sizes, due to the higher drying rates. The increase on maltodextrin addition also led to the production of larger particles, which is related to the increase on feed viscosity (Renata et al. 2008). Changing the levels of the independent variables allows for alterations in the final powder characteristics. Optimal product attributes will be determined depending on the desired application.

Overall, at the inlet air temperature of 170^{0}C, 10% maltodextrin addition and 1:1 durian to water ratio of the spray-dried powders have the best solubility, sensory evaluation and process yield results. Drying the durian juice above 180^{0}C has overall lead to inferior products due to nutrient loss. However, these results indicate that good quality powders can be produced by spray-drying durian juices for potential use.

5.2 Recommendations

Always start a trial with a low to medium temperature. Maximum air flow and a slow pump rate. Observe the bottom of the main chamber for wetting and either reduce the pumping rate or increase the temperature if the product is not completely dried. The optimum pumping or temperature rates are achieved when no wet spotting of the product is observed.

If the sample is a liquid with solid in suspension it may be necessary to keep it continually agitated with the magnetic or overheat stirrer. Heavy suspension are best pumped from the sample container when the positioned on the side shelf as this shelf, the pump and the jet are all at a similar weight. If the sample is pumped from the bench top the product may separate as it is being pumped upwards in the silicon tube

All the physical properties of the powders that being study in this research are very important to ensure the production of high quality durian powders. But there still a lot of properties of powders that need to be study in order to produce high quality of product. These include biological properties such as microbial activity. So as the recommendation, I suggest that further investigation is needed to address the surface stickiness issue and the morphology of the durian juice and powders itself in relation to the shelf life of the product.

The suitable anti-caking agent for durian powder is not found. Calcium Carbonate which is the ant-caking agent for soft drink were chosen since it is the nearest best comparison. Therefore further research should be done to identify the more suitable anti-caking agent to increase the quality of the durian powder and to increase its shelf life. Adoption of this technology could, therefore, open up a new market opportunity for the durian juice powders industry. For the unit technical, it's better if they increase the effectiveness of spray drying by doing regular maintenances. Other recommendation for unit technical is to increase the number of spray dried. This is to obtain the best result of experiment.

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APPENDIX

SENSORY ANALYSIS FORM

Instruction: Tick (√) in the relevent box

Criteria		Score Frequency				
		Very poor	Poor	Uncertain	Good	Very good
Appearance	Color					
	Size					
	Shape					
Flavor	Odor					
	Taste					
Texture	Mouth feel					
	Viscosity					
Total						