DEVELOPMENT OF SPRAY DRIED STRAWBERRY JUICE POWDER

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ABSTRACT

This study explains the process and the optimum parameters to dry strawberry juice using lab scale spray dryer. The optimum parameters are the optimum drying temperature for minimum loss of vitamin C during drying process and optimum Maltodextrine 10 percentage for optimum colour, texture and taste of strawberry juice powder. There are 4 analytical experiments conducted on the strawberry juice powder produced which are vitamin C lost percentage, solubility analysis, effect of anti-caking and sensory evaluation. The strawberry juice is used as feed for spray drying process and production of strawberry powder. Firstly, strawberry juice is spray dried with spray dryer at various temperatures from 160 ^{o}C to 200 ^{o}C. Then, for the second experiment drying temperature is set constant at 170 ^{o}C and percentage of Maltodextrine is manipulated from 10% to 30%. Analytical experiment is conducted to measure the qualities of powder produced. Firstly, vitamin C loss studied before and after drying process to determine percentage of loss due to drying at different temperature. Then the solubility analysis conducted for powder produced with different percentage of Maltodextrine 10 addition. Then, the effect of anti-caking is analyzed by producing strawberry juice powder with addition of anti-caking agent (calcium carbonate). Lastly, sensory evaluation is conducted at cafeteria where people randomly choose to evaluate the qualities of reconstituted strawberry juice and powder produced. From the analysis, minimum loss of vitamin C observed at low temperature and it gradually increases as temperature increased. Solubility increases with increases of Maltodextrine 10 percentage. Anti-caking agent decreases hygroscopicity and increases the shelf life of powder. From all the analysis it is concluded that optimum temperature for drying is at 170 ^{o}C with optimum percentage of Maltodextrine 10 addition is 25%. High quality product is produced and it has high market potential in the future.

ABSTRAK

Kajian yang dijalankan menerangkan proses dan parameter optima bagi proses pengeringan jus strawberi mengunakan pengering semburan. Parameter optima yang dikaji adalah suhu optima bagi proses pengeringan dengan kehilangan vitamin C yang minima dan peratusan Maltodextrine 10 optima bagi tekstur, warna dan rasa yang baik. 4 analisis dijalankan terhadap serbuk strawberi yang diperolehi iaitu peratusan kehilangan vitamin C, analisis keterlarutan, kesan 'anti-caking' dan penilaian deria. Jus strawberi digunakan sebagai bahan mentah bagi proses pengeringan dan penghasilan serbuk strawberi. Eksperimen dimulakan dengan proses pengeringan jus strawberi pada suhu yang berlainan iaitu dari 160 ^{o}C ke 200 ^{o}C. Kemudian, process pengeringan dijalankan dengan suhu tetap pada 170 ^{o}C tetapi peratusan Maltodextrine 10 ditukar dari 10% hingga 30%. Eksperimen analitis dimulakan dengan menyukat kepekatan vitamin C sebelum dan selepas proses pengeringan. Peratusan kehilangan vitamin C pada setipa suhu dikaji. Kemudian, analisis keterlarutan dikaji bagi setiap serbuk yang dihasilkan dengan peratusan Maltodextrine 10 yang berbeza. Selepas itu, kesan 'anti-caking' terhadap serbuk dikaji dengan menghasilkan serbuk strawberi dengan tambahan kalsium karbonat. Akhir sekali penilaian deria dijalankan terhadap serbuk strawberi di kaferia pelajar. Beberapa pelajar dipilh secara rawak dan diberi jus dan serbuk strawberi bagi menilai kualiti merujuk kepada borang penilaian yang diedarkan. Analisis menunjukan kehilangan vitamin C yang sedikit yang pada suhu rendah dan ia meningkat pada suhu yang tinggi. Manakala, keterlarutan serbuk meningkat dengan meningkatnya peratusan Maltodextrine 10. 'Anti-caking' mengurangkan *hygroscopicity* dan meningkatkan tempoh penggunan. Suhu optima bagi proses pengeringan adalah pada 170 ^{o}C dengan peratusan optima Maltodextrine 10 adalah 25%. Produk yang mempunyai kualiti dan potensi pemasaran tinggi telah diperoleh.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

IU	-	International Unit
HPLC	-	High Performance Liquid Chromatography
SD	-	Spray Dryer
UV	-	Ultra-Violet
C-8	-	Octyl Chain
C-18	-	Octadecyl Chain
RI	-	Refractive Index
Near-IR	-	Near-Infra Red
MS	-	Mass Spectroscopy
NMR	-	Nuclear Magnetic Resonance
LS	-	Light Scattering
FDA	-	Food and Drug Association
U.S.A	-	United States of America
ASQC -	-	American Society for Quality Control
RSD	-	Relative Standard Deviation
UV-DAD	-	Ultra Violet Diode Array Detection
KK1	-	Kolej Kediaman 1

LIST OF SYMBOLS

μ	-	Micro
t	-	Time
r	-	Radius
d_L	-	Density of liquid
H_v	-	Latent heat of vaporization
m_i	-	Initial moisture content
m_f	-	Final moisture content
h	-	Film coefficient for heat transfer
ΔT	-	Temperature difference
D_p	-	Diameter of particle
A_i	-	Inlet cross section area
z	-	Depth of separator
D	-	Diameter of separator
V_o	-	Velocity of air
d_S	-	Density of particle
μ	-	Viscosity of fluid
ppm	-	Part per million
$CaCO_3$	-	Calcium Carbonate
KH_2PO_4	-	Potassium Dihydrogen Phosphate
RPM	-	Resolution per minutes
W	-	Watt
V	-	Voltage
MeOH	-	Methanol

CHAPTER 1

INTRODUCTION

1.1 Background

Fruits are important sources of vitamins and carbohydrates like fiber and sugar. They are low in calories and naturally sweet. Fruits and their juices are good sources of water, too. Different fruits contain different vitamins, so it is important to eat a variety of fruits. Mangoes, papayas, melons and citrus fruits, like oranges and grapefruit, are high in vitamin C **(Romero, M.A. Rodriguez, *et al, 1992*).** Cantaloupe, apricots, peaches, and nectarines are sources of vitamin A **(Bates CJ, 1995)**. Referring to food guide pyramid, fruits are second most important food in our daily life. There is no harm of taking lots of fruits because it will supply us all kind of vitamins which is needed by our body. These vitamins are very important for human being as a supplement and to avoid various kind of sickness.

Nowadays, the fast economic development has changed the trend of food consumption from calories assurance to diet nutrient enrichment. The consumers today are well educated and well aware of importance of vitamins. This scenario has increased the global market demand towards the fresh fruits. In order to meet the market demand throughout the year in all areas; the fresh fruits is preserved using different techniques. High moisture content in fruit leads towards decrease of quality due to water activity. So, drying of fruits used to remove the moisture content and decrease the water activity which will decrease the quality of the fruits. Drying is an ancient technique of preservation which still being applied in this modern world.

Nowadays, a lot more drying techniques such as spray drying, freeze drying, tray drying have invented to increase the productivity and achieve better control of process to increase the product quality.

Strawberry, scientific name *Fragaria* × *ananassa* and family Rosaceae (rose family), low herbaceous perennials with edible red fruits, native to temperate and mountainous tropical regions **(See G. M. Darrow, 1966)**. The name is derived from Old English *strēawberiġe* which is a compound of *streaw* meaning "straw" and *berige* meaning "berry". The major producer of strawberry is United States of America and Europe countries. It is reported USA produces 1,053,240 tonnes of strawberry in year 2005 **(USDA Economics, 2005)**. Fresh strawberry is delicious fruit and is one of the most nutritious fruit. The typical composition of strawberry is listed in Table 1.1 **(Ensminger AH, *et al*, 1983)**. It shows that strawberry contains high quantities vitamin C, fiber and potassium. The vitamin C content of some fruits is compared in Table 1.2 **(Romero, M.A. Rodriguez, *et al*, *1992*)**. The table shows that strawberry is fourth highest vitamin C content among the fruits.

The fact that strawberries are available year round, offers us the perfect opportunity to add great taste and nutrition to our everyday meals. Research shows that 94% of Americans currently consume strawberries and it is strongly suggested that eating them more often will add to a person's overall long term health **(Hyson. D, 2002)**

In Malaysia strawberry is planted and produced at Cameron Highlands. It is the only place in Malaysia which has optimum weather and condition for plantation of strawberry. The cold and high humidity is the suitable place for plantation of the strawberry and it can be harvested the whole year. Currently, in market the following products are processed from strawberry; canned slices, concentrate, dehydrated products, jam, jelly, juice, puree, spread, syrup, flavors and yoghurt. Clarified and cloudy strawberry juice is at market. However, fresh strawberry juice powder is not available yet at market and will significant increases in demand of it in future.

Figure 1.1: Strawberry (*Fragaria* × *ananassa)*

Table 1.1: Composition of fresh Strawberry per 100g

Nutrient	Units	Amount
Proximates		
Water	g	91.570
Energy	kcal	30.000
Energy	kj	126.000
Protein	g	0.610
Total lipid (fat)	g	0.370
Carbohydrate, by difference	g	7.020
Fiber, total dietary	g	2.300
Ash	g	0.430
Minerals		
Calcium, Ca	mg	14.000
Potassium, K	mg	166.000
Vitamins		
Vitamin C, ascorbic acid	mg	56.700
Folate	mcg	17.700
Vitamin A, IU	IU	27.000

Table 1.2: Comparison of vitamin C content of some selected fruits

Fruits	Ascorbic Acid (mg/100g Fresh fruit)
Acerola	1300
Guava	300
Black Currant	210
Strawberry	57
Orange	50

1.2 Problem Statement

Strawberry (*Fragaria × ananassa)* the result of the hybridization of *F. chiloensis*, believed to be indigenous to Chile and to the mountains of W North America, with the wild strawberry (*F. virginiana*) of E North America **(See G. M. Darrow, 1966)**. The cultivated strawberries therefore big in size and have high water content. It is rich source of ascorbic acid (vitamin C) containing over 50 to 60 mg per 100g. The vitamin C is mainly found in the water content of the strawberry fruit. Therefore the strawberry juice should be consumed fresh in order to obtain all the nutrition. Clarified and cloudy strawberry juices are currently produced and may have greater market potential, but most of products are in liquid or cordial type. The drying technique also has been developed but process conditions for these products have not been determined to preservation purposes.

Preservation is very important because fresh strawberries are safe to be consumed within very short period. The strawberries are spoilt very fast and easily because of the water activity. Since strawberries have high water content, it is more prone to be spoilt if not stored and preserved well **(Ensminger AH, *et al,* 1983)**. Besides that, the geography condition of Cameron Highlands which is hilly and has moderate road system causes the transportation of the fresh strawberries not effective. The ineffective transportation system of strawberries in Malaysia leads to the fruit injuries. Since, the limited transportation available; a lot strawberries is loaded in big lorries and transported to whole Malaysia. This indirectly causes injuries to fruits because of being stacked and transported through hilly roads.

Therefore the drying technique of preservation has been a very efficient and precise method to solve all the problems occurred. Drying has capable of the reduction of the vitamin C content in strawberry juice due to change of temperature and oxidation. However, the product produced (instant strawberry powder) has high potential to be used in formulated drinks, baby foods and other foods. The cost of transportation would reduce significantly when transporting the product to market places. Besides that, the fruit injuries problem due to the transportation would be reduces to zero and directly there would be no lost to the farmers.

However, information about strawberry powders does not exist in the literature. Strawberry has best nutritional properties and drying operations must be carefully designed to maintain these nutritional properties. Vitamin C retention in different temperature and after dried must be investigated to determine the effect of temperature in reduction of Vitamin C. Water activity level or moisture content effect on strawberry juice is investigated through experiment and to design best drying operating condition with minimum lost of vitamin C from the study.

1.3 Objectives

The objectives of the research project are:

1. to produce strawberry powder by spray drying method
2. to optimize the processing parameters for production of strawberry powder
3. to measure the qualities of spray dried strawberry powder

1.4 Scope

The scopes for this project are:

1. strawberry used as the source of pure juice
2. Maltodextrine 10 used as the carrier agent
3. determine effect of drying at different temperature on vitamin C (selected index)
4. optimum drying temperature for minimum lost of vitamin C determined
5. optimum Maltodextrine 10 percentage determined to obtain powder with optimum texture color and solubility rate
6. sensory evaluation conducted to determine the quality (appearance, flavor and texture) of the strawberry juice powder produced

CHAPTER 2

LITERATURE REVIEW

2.1 Food Preservation

Food preservation is the process which deals with the practical control of factors capable of adversely affecting the safety, nutritive value, appearance, texture, flavor, and keeping qualities of raw and processed foods. Since thousands of food products differing in physical, chemical, and biological properties can undergo deterioration from such diverse causes as microorganisms, natural food enzymes, insects and rodents, industrial contaminants, heat, cold, light, oxygen, moisture, dryness, and storage time, food preservation methods differ widely and are optimized for specific products. **(Borgstrom, 1968)**

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 discoloration that can occur during food preparation such as the enzymatic browning reaction in apples which causes browning when apples 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. **(N. W. Desrosier, 1970)**

Common methods of applying these processes include drying, spray drying, freeze drying, freezing, vacuum-packing, canning, preserving in syrup, sugar crystallization, food irradiation, and adding preservatives or inert gases such as carbon dioxide. Other methods that not only help to preserve food, but also add flavor, include pickling, salting, smoking, preserving in syrup or alcohol, sugar crystallization and curing. **(N.W. Desrosier, 1970).** Although there are many food preservation methods, our concern in this research project is drying preservation technique.

2.2 Drying

Drying is an ancient method of food preservation technique which defined as the application of heat under controlled conditions to remove the majority of the water normally present in a food by evaporation. It is a complicated process involving simultaneous heat and mass transfer in which heat penetrates into the product and moisture is removed by evaporation into an unsaturated gas phase.

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. Drying method varies with the specific food and end products.

2.2.1 Drying Mechanism

The mechanism of moisture movement within the solid in drying process has received much attention in the literature and a significant number of drying theories have been developed. Mechanisms such as, molecular diffusion, capillary motion, liquid diffusion through solid pores, vapor diffusion in air-filled pores, Knudsen flow, vaporization condensation sequence flow and hydrodynamic flow were considered. These mechanisms are of particular importance for fruits and vegetables as product structure will influence the moisture movement. **Mujumdar** (1990) reviewed theories on the mechanism of moisture migration. Generally, there appear to be four probable major modes of transfer:

1. Liquid movement caused by capillary forces;
2. Liquid diffusion resulting from concentration gradients;
3. Vapor diffusion due to partial pressure gradients;
4. Diffusion in liquid layers absorbed at solid interfaces.

Foods can be classified as *hygroscopic* and *non-hygroscopic*. The partial pressure of water vapor in hygroscopic food varies with the moisture content, while that of non-hygroscopic food is constant at different moisture contents. Thus, non-hygroscopic foods have a single falling-rate period, whereas hygroscopic foods have two falling rate periods. In the falling rate periods, the rate of moisture movement within the solid and the effects of external factors.

Moisture transfer in drying is a complex process where different mechanisms can occur at the same time. In the process of drying, mechanisms may vary considerably. A realistic model should consider as many as of the different phenomenon (e.g., simultaneous heat and mass transfer, multi-dimensional transfer, material shrinkage) occurring in the course of drying. It may not be possible to use same drying model for different foods or drying conditions.

There are many drying method available to dry strawberry juice puree. However the spray drying method has higher nutrient retention compare to the other methods. **(Robert Harris and Endel Karmas, 1975).** The juice or puree is dispersed or atomized to form droplets and sprayed into a heated chamber where it is dried and forms a “free-flowing” powder. The more common technologies such as convection, cabinet and drum drying are more costly, more labor-intensive, more complicated, and more likely to cause “powder burns.”

2.3 Spray Dryer

2.3.1 Introduction

A spray dryer is a device used in spray drying. It takes a liquid stream and separates the solute or suspension as a solid and the solvent into a vapor. The solid is usually collected in a drum or cyclone. The liquid input stream is sprayed through a nozzle into a hot vapor stream and vaporised. Solids form as moisture quickly leaves the droplets. A nozzle is usually used to make the droplets as small as possible, maximising heat transfer and the rate of water vaporisation. Droplet sizes can range from 20 μm to 180 μm depending on the nozzle.

Spray dryers can dry a product very quickly compared to other methods of drying. They also turn a solution or slurry into a dried powder in a single step, which can be advantageous for profit maximization and process simplification.

2.3.2 Basics of Spray Drying

2.3.2.1 Concentration of Puree

Feedstock is normally concentrated earlier before 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. The feedstock for conventional big scale spray dryer normally will be concentrated to 50%-60% before introduced to spray dryer. However the small scale laboratory spray dryer will have more diluted feedstock because it will be clogged easily if the feed have high viscosity.

2.3.2.2 Atomization

Atomization refers to the conversion of bulk liquid into a spray or mist (i.e. collection of drops), often by passing the liquid through a nozzle. Despite the name, it does not usually imply that the particles are reduced to atomic sizes. The liquid which sprayed through nozzle will increase the surface area of the liquid which later will be contacted to hot air and dried into powder. The nozzle size may differ according to the size of spray dryer. Droplet sizes can range from 20 μm to 180 μm depending on the nozzle. Smaller spray dryer occupies smaller nozzles and reverse for the industrial scale spray dryer.

2.3.2.3 Droplet-air contact

The important component of spray dryer is the chamber; here the sprayed droplet is contacted with the hot air for the drying process. Air, which is, normally the drying media used, is heated to a predefined temperature depending upon the characteristics of the feed fluid and hot air is heated by the heating element which situated before entering the camber. This hot air is brought in contact with the spray droplets in one of the following ways through the air distributor.

1. Co-current-Air and particles move in the same direction.
2. Counter-current-air and particles move in the opposite direction.
3. Mixed flow - particles are subjected to co-current and counter-current phase.

The thermal energy of the hot air is used for evaporation and the cooled air pneumatically conveys the dried particles in the system. The contact time of the hot air and the spray droplets is only a few seconds, during which drying is achieved and the air temperature drops instantaneously. The nozzle which increases the contact area of droplet and hot air influences in huge heat transfer between the droplet and hot air. The hot air evaporates the moisture content in the droplet and changes it into powder form. The dried particle never reaches the drying air temperature. This enables efficient drying of heat sensitive materials without thermal decomposition. The most efficient way of spray droplet and hot air brought in contact is counter-current.

2.3.2.4 Droplet Drying

The droplet drying takes place in three periods. During the first period, the temperature increases to the wet bulb temperature. In the second period, a concentration gradient builds up in the drop and water activity at the surface decreases, thus causing the surface temperature to rise above that of the of the wet bulb temperature. In the final period, internal diffusion becomes limiting. Critical moisture content is eventually reached below which the surface becomes impenetrable. **(Karel, 1975)** Different products have differing evaporation and particle-forming characteristics. Some expand; others contract, fracture or disintegrate. The resulting particles may be relatively uniform hollow spheres, or porous and irregularly shaped.

The drying time for a single droplet may be estimated by the following equation:

$$t = \frac{r^2\, d_L H_V\ (m_i - m_f)}{3\ h\ (\Delta T)(1 +\ m_i)}$$

The typical drying time for an average milk droplet of 40 μ is only a fraction of a second. However, because of the great initial velocity, the particle will have traveled a considerable distance from the atomizer before it is dry (13.5 cm for average conditions). It should be noted, that the drying time is proportional to the square of the radius; thus, for larger droplets the drying time may become so long that the droplet reaches the wall of the dryer while still wet. This problem is often encountered in small scale dryers. The above equation also stresses that the drying time can be shortened by reducing the initial moisture content by pre-concentration of the liquid. **(Buma, 1971)**

2.3.2.5 Separation of Dry Particles

Separation is carried out partly within the drying chamber itself and partly in secondary separation equipment. In general, it is easy to remove 90% or more of the powder, but removal of the remainder becomes problematic. Cyclone separators operate on the 'momentum separation' principle (centrifugal action) and are extensively used in large scale dryers for removal of fines.

Charm (1971) has given an equation which relates the dimensions of a cyclone to the smallest particle (Dp) which can be separated:

$$D_p^2 = \frac{3.6\, A_i\, D_0 \mu}{Z D V_0 d_s}$$

From the equation it appears that in designing a cyclone the depth and diameter should be as large as possible. Increasing the air velocity is also important. Industrial experience has shown that efficiency is also affected by the powder concentration in the air stream. For this reason, it is better to use several cyclones in parallel than just one single separator.

2.3.2.6 Powder Collection

As the powder is separated with the cold air by the cyclone separator, the dried powder will drop through the opening at the bottom of cyclone. So, there will be a container which is attached to the cyclone for recovery of the powder produced. The powder primary recovered from the drying chamber and collected into separate container. The conventional spray dryer is equipped with hammer which will give vibration to the wall of the drying chamber and drop all the powder that stick at wall of the chamber. The small scale sprayer does not facilitate with such advantage and it is done manually.

2.3.3 Advantage of Spray Dryer

In the world of industrial dryers, there are few types that accept pump able fluids as the 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. Advantages of spray drying are as follows:

- Able to operate in applications that range from aseptic pharmaceutical processing to ceramic powder production.
- Can be designed to virtually any capacity required. Feed rates range from a few pounds per hour to over 100 tons per hour.
- Powder quality remains constant during the entire run of the dryer.
- Operation is continuous and adaptable to full automatic control.
- A great variety of spray dryer designs are available to meet various product specifications.
- Can be used with both heat-resistant and heat sensitive products.
- As long as they are can be pumped; the feedstock can be abrasive, corrosive, flammable, explosive or toxic.
- Feedstock can be in solution, slurry, paste, gel, suspension or melt form.
- Product density can be controlled
- Nearly spherical particles can be produced.
- Material does not contact metal surfaces until dried; reducing corrosion problems.