PHYSICAL PROPERTIES OF SOURSOP (*ANNONA MURICATA*) POWDER PRODUCED BY SPRAY DRYING

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“I hereby declare that I have read this dissertation and in my opinion this dissertation has fulfilled the qualities and requirements for the award of the degree of Bachelor of Engineering (Chemical Engineering)”

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A dissertation submitted in partial fulfillment of the
requirements for the award of the degree of
Bachelor of Engineering (Chemical Engineering)

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`I declare that this dissertation entitled "Physical Properties of Soursop (*Annona Muricata*) Powder Produced by Spray Drying" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my beloved mother, Kamariah Bt Osman

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ABSTRACT

The growing of fruits is limited in many countries to certain seasons and localities. In order to meet the demand of the market throughout the year in all areas, the commodities are preserved using different techniques. Actually, this research, is a about soursop fruits. Soursop fruit does not travel well and is rarely available fresh in areas where it is not grown. Nutritionally, the soursop fruit is high in carbohydrates, particularly fructose and also contains significant amounts of vitamin C, vitamin B1, and vitamin B2. Parts of the soursop tree are used in natural medicine in the tropics, including the bark, leaves, roots, fruit, and fruit seeds. The fruit and fruit juice are taken for worms and parasites, to cool fevers, to increase mother's milk after childbirth, and as an astringent for diarrhea and dysentery. Spray drying has become the most important method for the dehydration of fluid foods such as juices. This study is undertaken to investigate the feasibility of spray drying of soursop juice and to evaluate the physical properties of the powder produced. Independent variables were: inlet air temperature (160–190 °C) and maltodextrin concentration (10–25% of total feed solution). Moisture content, hygroscopicity, process yield, solubility and dissolution were analyzed as responses. Powder moisture content and process yield were positively affected by inlet air temperature which is directly related to heat and mass transfer. Process yield was also negatively influenced by maltodextrin concentration. Powders hygroscopicity decreased with increasing maltodextrin concentration and decreasing temperature. Powders with lower moisture content were more hygroscopic, which is related to the greater water concentration gradient between the product and the surrounding air. The result shows the optimum condition for Inlet Air Temperature is 170^0C. While for maltodextrin concentration is 10%.

ABSTRAK

Pada hakikatnya, buah durian belanda mempunyai keistimewaan tersendiri untuk diterokai. Buah ini tidak boleh dieksport dan jarang sekali didapati segar di kawasan di mana bukan habitatnya. Dari segi kesihatan, buah durian belanda adalah kaya dengan karbohidrat, terutama fruktosa dan juga mengandungi vitamin C, vitamin B1, dan vitamin B2. Penduduk di kawasan pedalaman membuat ubat-ubatan tradisional daripada bahagian-bahagian pokok durian belanda termasuk kulit, daun, akar, buah, dan biji benih. Buah dan jus durian belanda biasanya diambil untuk menghapuskan cacing dan parasit dalam badan, mengurangkan demam, meningkatkan susu ibu selepas bersalin dan sebagai astrigen untuk cirit-birit. Proses pengeringan sembur merupakan kaedah penting yang banyak digunakan dalam pengeringan makanan seperti jus buah-buahan. Kajian ini dijalankan untuk mengkaji keberkesanan proses ini bagi jus durian belanda dan untuk menentukan ciri-ciri fizikal bagi serbuk yang dihasilkan. Pembolehubah tidak bersandar adalah: suhu udara (160–190 °C) dan penambahan maltodekstrin (10–25% daripada jumlah jus yang digunakan). Kandungan lembapan, higroskopian, kelarutan dan jumlah keseluruhan kandungan pepejal dianalisis sebagai tindakbalas. Kandungan lembapan dan jumlah keseluruhan kandungan pepejal bagi serbuk yang dihasilkan dipengaruhi oleh suhu udara yang mana berkaitan dengan pemindahan haba dan jisim. Jumlah keseluruhan kandungan pepejal juga dipengaruhi oleh penambahan maltodekstrin. Penambahan maltodekstrin dan pengurangan suhu udara menyebabkan serbuk higroskopian berkurang. Serbuk dengan kandungan lembapan lebih rendah adalah lebih higroskopik, yang berkaitan dengan perbezaan kepekatan air antara produk dan udara sekeliling. Keputusan menunjukkan keadaan optimum untuk suhu udara adalah 170^0C. Manakala untuk penambahan maltodekstrin adalah 10%.

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CHAPTER 1

INTRODUCTION

1.1 Background

The growing of fruits and vegetables is limited in many countries to certain seasons and localities. In order to meet the demand of the market throughout the year in all areas, the commodities are preserved using different techniques. Due to their high value and wide appeal to consumers, fruits and vegetables have always been of interest to food scientists as raw materials for processed products. The most frequent reason for quality deterioration of food products is the result of microbial activity and this often results in food molding, fermenting and change in acidity. In addition, native enzymes in fruits may cause desirable and undesirable effects before, during or after processing of fruit juices. In order to complete my undergraduate research project and with a supported reason above, I choose food engineering as my major topic of research. My research will fully concentrate on preservation of fruits. The fruit that attract my intention is soursop while the preservation technique is drying.

There are about 60 or more species of the genus *Annona*, family *Annonaceae*. But from that entire species, the soursop is the most tropical and only itself is best suit for preserving and processing.

Figure 1.1: Soursop Fruit

- **Common Name: Soursop**
- **Vernacular Names: Sour sop, Guanabana, Soursap**
- **Scientific Name: Annona muricata**
- **Specimens From: Malaysia**

The soursop is also known as soursap, guanábana, graviola, sirsak, zuurzak, coração-da-índia, guyabano or corossol. Soursop or in scientific name, Annona muricata L. is one of the exotic fruits prized for its very pleasant, sub-acid, aromatic and juicy flesh. It is related to pawpaw and custard apple and around 30 tonnes are grown in Australia every year in tropical north Queensland. It is also native to the Caribbean, Central and South America. In the USA it has limited production in Florida. Soursop, known as a native fruit from the West Indies, Central America, down to Brazil and it is a common fruit in tropical Asia nowadays. The soursop tree is actually trees that comes from the Caribbean and northern South America. Today the soursop has spread throughout the humid tropics so it is also grown in Southeast Asia included Malaysia and Indonesia. This fruit can be round, oval or irregular heart shaped. Some cultivars are huge, almost the size of a watermelon. It is dark green when unripe and will turn yellowish-green and slightly soft when it matures. Black blotches will start to appear and that indicates overripe.

As mention above, Soursop (Annona muricata L.) is a common fruit in tropical Asia so it is one of the popular exotic fruits in Malaysia. Soursop also is one of the most nutritious fruits in the tropical region. The white cottony pulp is very juicy, varying in flavour from acid to sweet and highly regarded because of its distinctive aroma and flavour. The flesh or pulp that is creamy white in color and has the texture of juicy candy floss interlaced with black seeds. The taste is not sour as the name suggests but sweet and musky. The flavour was tropical, strong and pungent on entry but with a delicate ending and a soothing creamy aftertaste. They taste similar to lychees but also have a ripe purée pear and bitey pineapple edge to them.

Soursop is extremely juicy and seedy; hence it is quite a messy fruit to eat. The skin may look leathery but it tears easily. Just cut it like you would cut a watermelon. The interior texture may not look nice but the taste is refreshing and flavorful. However, it softens very rapidly during ripening and becomes mushy and difficult to consume fresh. It is rejected at market because of external injury, or uneven shape and size. It is mostly eaten as fresh fruits. Therefore, soursop can become a potential source of raw material for puree, juice, jam, jelly, powder fruits bars and flakes. It is also excellent for making refreshing drinks, sherbets and flavoring/topping for ice-cream and dessert. It is classified as a premium tropical fruit. As such, it offers potential for the soft drink industry.

But at the same time, the soursop is usually juiced rather than eaten directly because of the white interior pulp is full with many seeds, and pockets of soft flesh are bounded by fibrous membranes. Furthermore, this fruit does not travel well and is rarely available fresh in areas where it is not grown. This is because soursop is a highly perishable fruit with short shelf life. Once the juice has been extracted and placed in storage it will need considerable treatment before being acceptable to the consumer. So that, juiced powder is other alternative to consume this fruit in fresh condition.

Several methods may be used for production of juiced powder, but the most successful include freeze-drying, foam mat drying, spray drying and tunnel drying. Researchers have successfully used freeze drying to convert juiced products into powder although freeze drying is known to be the most expensive method of drying. Tunnel drying is well known to be the cheapest method of drying an acceptable quality powder. The foam-mat drying process is a relatively simple and inexpensive process. One difficulty that has previously been experienced with this process, however, is the lack of stability of the foam during the heating cycle. If the foam does not remain stable, cellular breakdown occur causing serious impairment of the drying operation. But dehydration by means of spray drying is a technique which widely used to produce fruit juices powders ([Abadio et al., 2004], [Cano-Chauca et al., 2005] and [Quek et al., 2007]) and it has been proven to be an effective method to obtain various products.

Spray drying has become the most important method for the dehydration of fluid foods such as milk, coffee and egg powder, and is also used extensively in the pharmaceutical and chemical industries. It is a method whereby solutions or slurries are rapidly dried to particulate form by atomizing the liquid in a heated chamber. Typically performed using aqueous systems, spray drying can also be undertaken with solvent-based systems under controlled conditions.

Spray drying is a process to convert small liquid droplets into dried powder in contact with hot air. Rapid evaporation maintains droplet temperature at low level, so that high drying air temperatures can be applied without affecting the product quality. The drying time of the droplets in spray dryer is very short in comparison with most other drying processes. There are many type of dryer such as constant bed dryer, fluidize bed dryer and microwave dryer that used hot air flow for drying foods. The cyclone spray dryer is the most commonly used. Typically, a liquid product concentrate is pumped to the atomizing device where it is broken into small droplets. These droplets meet a stream of hot gas and lose moisture very rapidly while suspended in the drying air. The dry powder is separated from the moist air in cyclones by centrifugal action. The atomizer comprises either a spinning disc (rotating at 2000-20,000 rpm) or static high velocity jet nozzles. Hot air contacts with solid products such as grains, vegetables and fruits pulps and dry them. These dryers need long time for drying processes. Low product temperature and short drying time allow spray drying of very heat sensitive products such as foods, dairy products and fruit juices. Powder that produced by it is in a good quality, low water activity and easier transport and storage. This is due to the reduction of volume and longer shelf life. Besides, spray dried powder was stable and could be produced at a lower cost.

Spray drying consists of the following unit operations:

- Pre-concentration of liquid (for more economic operation, since evaporation is expensive)
- Atomization (creation of droplets)
- Drying in stream of hot, dry gas (usually air)
- Separation of powder from moist gas
- Cooling
- Packaging of product

The process of materials in spray dryers is a complex interaction involving apparatus, process and product parameters, which affects the final quality of the materials. The quality of spray dried food is quite dependent on the spray dryer operating parameters. The spray drying process is greatly affected by feed flow rate, inlet-air temperature, atomizer speed, feed concentration, feed temperature, inlet air flow rate and etc. (Chegini, Ghobadian, & Barecatin, 2005).

Atomization is of particular interest to the metal industry for generating fine powders. Generally it is carried out using an inert carrier gas. This gas forces molten powder (notably aluminum or solder) through a nozzle and then cools the droplets into highly spherical powders. The physics of gas atomization of metal powders involves multiphase gas flow, heat transfer, droplet formation, and solidification. Interaction between these individual mechanisms complicates understanding and modeling of the process. In addition, the chemical activity between some metals introduces further complexity. The challenge is to increase the powder yield, improve the powder quality and reduce the production cost. This requires both a thorough understanding of the process and a comprehensive experimental investigation in order to guide the design of the gas atomizer and to determine optimal settings of critical process variables.

Therefore, it is important to optimize the drying process in order to obtain products with better performance included sensory and nutritional characteristics and better process yield. In addition to the powder production, the quality of food spray dryer depend the operating variables. Studying the effect of operating parameters on powder physical properties help us in obtaining the optimum operating conditions of spray dryer and powder characteristics.

1.2 Problem Statement

Several varieties of the fruits are grown for export and for local consumption. Some of the fruit is, however, wasted at the production points due to nonavailability of sufficient storage, transportation and processing facilities. Soursop utilization as we can see whether in the producer country or for export to premium markets have always been limited by the perishable nature of the fruits. As mention earlier, soursop also known as *Annona Muricata* is one of exotic fruits. It is a well-known fruit throughout much of world because of its delicious white pulp and has pleasantness sub acid taste that is very exquisite. Those characteristics make soursop very unique fruits and have higher ability to be commercialized. Soursop can be found in tropical market, but is rarely found fresh anywhere else due to its short shelf life. The soursop is adapted to areas of high humidity and relatively warm. While, temperatures below 5 ^{o}C will cause damage to leaves and small branches, and temperatures below 3 ^{o}C can be fatal to the soursop trees. In association with this climates problem, most of these products present high water content, making them more susceptible to decomposition by microorganisms, chemical and enzymatic reactions. Therefore, these products are extremely perishable and cannot be marketed or exported as fresh produce. Furthermore, soursops are quite costly these days, and many fruit vendors do not like to stock them because they ripened very quickly, and cannot be stored for long.

One of the alternatives to overcome those problems is to make soursop juice, so that every country can taste the freshness of soursop pulp at every second of time. But in the same time, freshly expressed juice, is highly susceptible to spoilage, in fact more so than whole fruit. Unprotected by skin or cell walls, fluid components are thoroughly mixed with air and microorganism from the environment. Thus, unheated juice is subject to rapid microbial, enzymatic, chemical and physical deterioration. The goal of processing is to minimizing these undesirable reactions while still maintaining and in cases enhancing, the inherent quality of the starting fruit (Bates et al., 2001).

The most frequent reason for quality deterioration of food product is the result of microbial activity and this often result in food molding, fermenting and change in acidity. Concentrated fruits juice also cannot stand longer; therefore productions of juice powder are very suitable to fulfill any transportation conditions. Juice powders allow longer periods of storage, minimize packaging requirements and reduce shipping weight. At the same time, the soursop often made into juice because eating raw is a somewhat messy proposition.

All parts of the soursop, including the skin and seeds, are poisonous except for the fruit itself. A very suitable condition must be investigated to determine temperature effect and water activity level or moisture content effect on soursop juice and at the same time to design best drying process. As in this research, spray drying was used. But fruit juice powders obtained by spray drying may have some problems in their properties, such as stickiness, hygroscopicity and solubility, due to the presence of low molecular weight sugars and acids, which have low glass transition temperature (Bhandari et al., 1993). Thus they can stick on the dryer chamber wall during drying, leading to low product yield and operational problems. Part of these problems can be solved by the addition of some carrier agents, like polymers and gums, to the product before being atomized. Besides reducing powder hygroscopicity, such agents, normally used for microencapsulating, can protect sensitive food components against unfavorable ambient conditions, mask or preserve flavors and aromas, reduce the volatility and reactivity and provide additional attractiveness for the merchandising of food products (Ré, 1998).

Some researchers have used carrier agents in order to protect sensitive components like vitamin C in fruits such as camu–camu juice and to increase product stability in acerola powder. In the case of açai juice, spray drying with carrier agents represents an interesting process, which can promote the protection of anthocyanins against adverse conditions like heat, light and oxygen, besides resulting in less hygroscopic powders. For this experiment, carrier agent that was being used are maltodextrin. Addition of maltodextrin could increase the total solid content in the feed and thus, reduce the moisture content of the product. It was suggested that maltodextrin could alter the surface stickiness of low molecular weight sugars such as glucose, sucrose and fructose and organic acids, therefore, facilitated drying and reduced the stickiness of the spray-dried product.

1.3 Objectives of the Study

There are considerably substantial amount of works on spray drying of fruit juice up-to-date. However, there have been limited scientific literatures concerning drying of soursop juice. Based on the above reasons, this study is undertaken to investigate the feasibility of spray drying of soursop juice and to evaluate the physicochemical properties of the powder produced. Due to a lack of studies on the influence of the process variables on the physicochemical properties of soursop powdered juices, the research was studied to achieve the following objectives:

1. To produce soursop powders using spray drying.
2. To study the influence of inlet air temperature and maltodextrin concentration on process yield of soursop powders.
3. To study the hygroscopicity, dissolution, solubility and sensory evaluation of powders obtained.

1.4 Scope of Study

In order to achieve the objectives, the following scopes have been identified:

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

1.5 Rationale and Significance

This study is to obtain the best product of soursop that has higher values in market. Soursop is one of exotic fruits that have higher potential to be commercialized. Since the soursop is rarely found and is a seasonal fruit, thus the food industry is constantly looking for inexpensive and more stable stages of sources. One of the best solutions is by producing juice powder of soursop. Several researches must be done before the best quality of soursop juice powder can be obtained. Powders obtained by drying concentrated fruits juices or pulps could represent interesting commodities. If all the research is successful, all part of the world can consume fresh distinctive aromatic qualities of soursop.

Others rationale that we can elaborate is saving cost in terms of transportation. Transportation costs would be reduced significantly when shipping this product to distant markets. At the same time, dried product would provide a stable, natural ingredient that could be easily manipulated and used in formulated foods.

CHAPTER 2

LITERATURE REVIEW

2.1 Soursop, *Annona muricata*

2.1.1 Name History

The soursop, *Annona muricata* L., is one of the exotic fruits that can be found in Malaysia. Actually there are about 60 or more species of the genus *Annona*, family *Annonaceae* but the largest-fruited, and the only one lending itself well to preservation and processing is *Annona Muricata.* It is a broadleaf flowering evergreen tree native to Mexico, Central America, the Caribbean and northern South America. Nowadays, it is also grown in some areas of Southeast Asia. Thus, there will be a different name for soursop in a different country. In Malaysia it may be called *durian belanda, durian maki*; or *seri kaya belanda*. The name may have originally come from the Dutch "zuurzak", which is also used in the Netherlands Antilles and Indonesia; but the derivation is uncertain. The Malay name does indicate this Dutch origin. The word "Belanda" means Hollander and was used to indicate something foreign and made known by the Dutch. Because the fruit is spiny, the word "durian" was also applied to indicate its similarity to the familiar durian fruit. This interpretation indicates that the fruit was "foreign", but resembled something "familiar" or already known and has resulted in other interesting etymology of that region. "Halwa belanda" means chocolate and "kuching belanda" means "foreign cat' or "rabbit", which was also introduced into Malaysia. Soursop is also known as "western durian" among the Chinese community, mainly because of the soft spikes on the skin that look similar to the durian. But it is totally unrelated, as in fruit family classifications, and tastes totally different too.

2.1.2 Description

The soursop tree is low-branching and bushy but slender because of its upturned limbs, and reaches a height of 25 or 30 ft (7.5-9 m). The malodorous leaves, normally evergreen, are alternate, smooth, glossy, dark green on the upper surface, lighter beneath; oblong, elliptic or narrowobovate, pointed at both ends. The small trees bear their fruit indiscriminately on twigs, branches and trunk. These fruits range in size from four to twelve inches in length, and up to about ten pounds in weight. They can be oval or irregularly shaped as one side usually grows faster than the other. The fruit is more or less oval or heart-shaped, some times irregular, lopsided or curved, due to improper carper development or insect injury. The size ranges from 4 to 12 inches long and up to 6 inches in width and the weight may be up to 10 or 15 pounds. The fruit is compound and covered with a reticulated, leathery-appearing but tender, inedible, bitter skin from which protrude few or many stubby, or more elongated and curved, soft, pliable "spines". The tips break off easily when the fruit is fully ripe. The thin skin has a leathery appearance, but is surprisingly tender. This skin is a dark green, but later turns yellowish-green, and finally all yellow when over-ripe. Because of the soft spines on the skin, the soursop is sometimes called the prickly custard apple. The white flesh consists of numerous segments. If there are seeds, they cannot be eaten as they contain toxins. The fruits are picked while still firm and said to be at their best if eaten five or six days later. The flavour varies from poor (like wet cotton) to very good, but it is more acidic than its relatives. The aroma is like that of a pineapple. Depending on the variety, some can be opened like a melon and eaten raw; while others, especially unripened fruit is best used as a vegetable. When boiled, it has the flavour of corn. Large fruit of soursop may contain from a few dozen to 200 or more seeds.

2.1.3 Climate

The soursop is truly tropical. This was proven in much country that possesses soursop trees. All young trees in exposed places in southem Florida are killed by only a few degrees of frost. The trees that survive to fruiting age on the mainland are in protected situations, close to the south side of a house and sometimes near a source of heat. Even so, there will be temporary defoliation and interruption of fruiting when the temperature drops to near freezing. In Key West, where the tropical breadfruit thrives, the soursop is perfectly at home. In Puerto Rico, the tree is said to prefer an altitude between 800 and 1,000 ft (244300 m), with moderate humidity, plenty of sun and shelter from strong winds. From this situation, the researchers have jump to conclusion that the soursop is adapted to areas of high humidity and relatively warm winters. The temperatures below 5 °C will cause damage to leaves and small branches while temperatures below 3 °C can be fatal. In the tropics, soursops are grown from sea level to 1000m, particularly in humid regions where the tree grows particularly well. In addition, soursops cannot tolerate standing water, and its roots are shallow, so it does not require a very deep soil base. As the best growth of soursop is achieved in deep, rich, well-drained, semi-drysoil, but the soursop tree can be and is commonly grown in acid and sandy soil.

2.1.4 Harvesting

The soursop tends to flower and fruit more or less continuously, but in every growing area there is a principal season of ripening. The fruit is picked when full grown and still firm but slightly yellow-green. If allowed to soften on the tree, it will fall and crush. It is easily bruised and punctured and must be handled with care. Firm fruits are held a few days at room temperature. When eating ripe, they are soft enough to yield to the slight pressure of one's thumb. Having reached this stage, the fruit can be held 2 or 3 days longer in a refrigerator. The skin will blacken and become unsightly while the flesh is still unspoiled and usable. Studies of the ripening process have determined that the optimum stage for eating is 5 to 6 days after harvest, at the peak of ethylene production. Thereafter, the flavor is less pronounced and a faint off odor develops. In Venezuela, the chief handicap in commercial processing is that the fruits stored on racks in a cool shed must be gone over every day to select those that are ripe and ready for juice extraction.

2.1.5 Nutrition and Medical Uses

Table 2.1: Nutrient values and weights are for edible portion of Soursop, raw

Nutrient	Units	Value per 100 grams	Number of Data Points	Std. Error	1.00 X 1 cup, pulp ------- 225g	1.00 X 1 fruit (7" x 5-1/4" dia) ------- 625g
Proximates						
Water	g	81.16	1	0	182.61	507.25
Energy	kcal	66	0	0	148	412
Energy	kj	276	0	0	621	1725
Protein	g	1.00	0	0	2.25	6.25
Total lipid (fat)	g	0.30	0	0	0.68	1.88
Ash	g	0.70	0	0	1.57	4.38
Carbohydrate, by difference	g	16.84	0	0	37.89	105.25
Fiber, total dietary	g	3.3	0	0	7.4	20.6
Sugars, total	g	13.54	0	0	30.46	84.62
Minerals						
Calcium, Ca	mg	14	0	0	32	88
Iron, Fe	mg	0.60	0	0	1.35	3.75
Magnesium, Mg	mg	21	1	0	47	131
Phosphorus, P	mg	27	0	0	61	169
Potassium, K	mg	278	3	12.676	626	1738
Sodium, Na	mg	14	3	5.526	32	88
Zinc, Zn	mg	0.10	0	0	0.23	0.62
Copper, Cu	mg	0.086	0	0	0.193	0.537
Selenium, Se	mcg	0.6	0	0	1.4	3.8
Vitamins						
Vitamin C, total ascorbic acid	mg	20.6	16	1.503	46.4	128.8
Thiamin	mg	0.070	0	0	0.158	0.438
Riboflavin	mg	0.050	0	0	0.113	0.312
Niacin	mg	0.900	0	0	2.025	5.625
Pantothenic acid	mg	0.253	0	0	0.569	1.581
Vitamin B-6	mg	0.059	1	0	0.133	0.369

Folate, total	mcg	14	0	0	32	88
Folate, food	mcg	14	0	0	32	88
Folate, DFE	mcg_DFE	14	0	0	32	88
Choline, total	mg	7.6	0	0	17.1	47.5
Vitamin A, IU	IU	2	6	1.476	4	12
Vitamin A, RAE	mcg_RAE	0	6	0.074	0	0
Retinol	mcg	0	0	0	0	0
Vitamin E (alpha-tocopherol)	mg	0.08	0	0	0.18	0.50
Vitamin K (phylloquinone)	mcg	0.4	0	0	0.9	2.5
Lipids						
Fatty acids, total saturated	g	0.051	0	0	0.115	0.319
16:0	g	0.040	0	0	0.090	0.250
18:0	g	0.011	0	0	0.025	0.069
Fatty acids, total monounsaturated	g	0.090	0	0	0.203	0.562
16:1 undifferentiated	g	0.004	0	0	0.009	0.025
18:1 undifferentiated	g	0.085	0	0	0.191	0.531
Fatty acids, total polyunsaturated	g	0.069	0	0	0.155	0.431
18:2 undifferentiated	g	0.069	0	0	0.155	0.431
Amino acids						
Tryptophan	g	0.011	1	0	0.025	0.069
Lysine	g	0.060	1	0	0.135	0.375
Methionine	g	0.007	1	0	0.016	0.044

USDA National Nutrient Database for Standard Reference, Release 20 (2007)

Nutritionally, the soursop fruit is high in carbohydrates, particularly fructose. The fruit also contains significant amounts of vitamin C, vitamin B1, and vitamin B2. As a general knowledge, all parts of the soursop tree are used in natural medicine in the tropics, including the bark, leaves, roots, fruit, and fruit seeds. Different properties and uses are attributed to the different parts of the tree. Generally, the fruit and fruit juice are taken for worms and parasites, to cool fevers, to increase mother's milk after childbirth, and as an astringent for diarrhea and dysentery. The crushed seeds are used against internal and external parasites, head lice, and worms. The bark leaves, and roots are considered sedative, antispasmodic, hypotensive, and nervine. The tea, fruit, and juice of soursop are used medicinally to treat illness ranging from stomach ailments to worms. The soursop also is considered a great ally in the treatment of over twelve different kinds of cancer. It is also used to treat rheumatism and inflammations.

Soursop has a long, rich history of use in herbal medicine as well as a lengthy recorded indigenous use. In the Peruvian Andes, a leaf tea is used for catarrh (inflammation of mucous membranes) and the crushed seed is used to kill parasites. In the Peruvian Amazon the bark, roots, and leaves are used for diabetes and as a sedative and antispasmodic. Indigenous tribes in Guyana use a leaf and/or bark tea as a sedative and heart tonic. In the Brazilian Amazon a leaf tea is used for liver problems, and the oil of the leaves and unripe fruit is mixed with olive oil and used externally for neuralgia, rheumatism, and arthritis pain. In Jamaica, Haiti, and the West Indies the fruit and/or fruit juice is used for fevers, parasites and diarrhea; the bark or leaf is used as an antispasmodic, sedative, and nervine for heart conditions, coughs, flu, difficult childbirth, asthma, hypertension, and parasites.

Many active compounds and chemicals have been found in soursop, as scientists have been studying its properties since the 1940s. Most of the research on soursop focuses on a novel set of chemicals called Annonaceous acetogenins. Annonaceous acetogenins are powerful phytochemicals found in the Annona Muricata plant which has a long and rich history of use in herbal medicine as well as a long recorded indigenous use in the Amazon region. Its many uses in natural medicine have been validated by this scientific research. The earliest studies were between 1941 and 1962. Several studies over the years have demonstrated that leaf, bark, root, stem and seed extracts of Annona Muricata are antibacterial in vitro against numerous pathogens and that the bark has antifungal properties. Annona Muricata seeds demonstrated active antiparasitic properties in a 1991 study, and a leaf extract showed to be active against malaria in two other studies in 1990 and 1993. In an 1976 plant screening program by the National Cancer Institute, the leaves and stem of Graviola showed active cytotoxicity against cancer cells and researchers have been following up on this research ever since. Mode of action studies in three separate laboratories have recently determined that acetogenins are superb inhibitors of Complex I in mitochondrial electron transport systems from several organisms including tumors. Research on various Annona species of plants has yielded many extremely potent acetogenins. Active compounds from soursop and other Annona plants have been submitted to the NIH anti-AIDS screen by Purdue University and their work is continuing with a number of other active plant species in the Annona plant family.

Actually there are thousand more benefits of soursop fruits that are very ridiculous to believe, but that's the truth of soursop. Set in our mind that not only the fruits of soursop are useful but at the same time tree-trunk, root and seeds of it have their own beneficial value in daily life.

2.1.6 Food Uses

The soursop is usually processed into ice creams (Gratao et al, 2007), sherbets and drinks because of its delicious white pulp with tones of fruit candy. Soursop juice is a popular beverage throughout Southeast Asia and is available canned or bottled. The canned pulp can be pureed or blended in the home, and easily transformed into a delicious desert, although fresh pulp is more desirable. While, for fiber-free varieties of soursop, there are often eaten raw.

As mention earlier, from the 60 or more species of the genus Annona, family Annonaceae, the soursop, Annona muricata L., is the most tropical, the largest-fruited, and the only one lending itself well to preserving and processing. Because of that reason, many countries have different way in serving the soursop fruits. Below are some of techniques in serves soursop fruits in different location of world.

Soursops of least acid flavor and least fibrous consistency sometimes are cut in sections and the flesh eaten with a spoon. The seeded pulp may be torn or cut into bits and added to fruit cups or salads, or chilled and served as dessert with sugar and a little milk or cream. For years, seeded soursop has been canned in Mexico and served in Mexican restaurants in New York and other northern cities. Most widespread throughout the tropics is the making of refreshing soursop drinks (called champola in Brazil; carato in Puerto Rico). For this purpose, the seeded pulp may be pressed in a colander or sieve or squeezed in cheesecloth to extract the rich, creamy juice, which is then beaten with milk or water and sweetened. Or the seeded pulp may be blended with an equal amount of boiling water and then strained and sweetened. If an electric blender is to be used, one must first be careful to remove all the seeds, since they are somewhat toxic and none should be accidentally ground up in the juice.

In Puerto Rican processing factories, the hand-peeled and cored fruits are passed through a mechanical pulper having nylon brushes that press the pulp through a screen, separating it from the seeds and fiber. A soursop soft drink, containing 12 to 15% pulp, is canned in Puerto Rico and keeps well for a year or more. The juice is prepared as a carbonated bottled beverage in Guatemala, and a fermented, cider-like drink is sometimes made in the West Indies. The vacuum-concentrated juice is canned commercially in the Philippines. There soursop drinks are popular but the normal "milk" color is not. The people usually add pink or green food coloring to make the drinks more attractive. The strained pulp is said to be a delicacy mixed with wine or brandy and seasoned with nutmeg. Soursop juice, thickened with a little gelatin, makes an agreeable dessert. In the Dominican Republic, a soursop custard is enjoyed and a confection is made by cooking soursop pulp in sugar sirup with cinnamon and lemon peel. Soursop ice cream is commonly frozen in refrigerator ice-cube trays in warm countries. In the Bahamas, it is simply made by mashing the pulp in water, letting it stand, then straining to remove fibrous material and seeds. The liquid is then blended with sweetened condensed milk, poured into the trays and stirred several times while freezing. A richer product is made by the usual method of preparing an ice cream mix and adding strained soursop pulp just before freezing. Some Key West restaurants have always served soursop ice cream and now the influx of residents from the Caribbean and Latin American countries has created a strong demand for it. The canned pulp is imported from Central America and Puerto Rico and used in making ice cream and sherbet commercially. The pulp is used, too, for making tarts and jelly, sirup and nectar. The sirup has been bottled in Puerto Rico for local use and export. The nectar is canned in Colombia and frozen in Puerto Rico and is prepared fresh and sold in paper cartons in the Netherlands Antilles. The strained, frozen pulp is sold in plastic bags in Philippine supermarkets.

Immature soursops are cooked as vegetables or used in soup in Indonesia. They are roasted or fried in northeastern Brazil. I have boiled the half-grown fruit whole, without peeling. In an hour, the fruit is tender, its flesh off-white and mealy, with the aroma and flavor of roasted ears of green corn (maize).

2.2 Drying

Soursop fruits do not travel well and is rarely available fresh in areas where it is not grown. In order to overcome this problem, soursop must undergo certain preservations process before being consume. One of it is, drying process. In drying process, soursop juice is being converted to soursop juice powder. Drying is 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.

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. 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.

The main purpose of drying is to allow longer periods of storage, to minimize packaging requirements and to reduce shipping weight, and powders 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.

2.3 Spray Drying

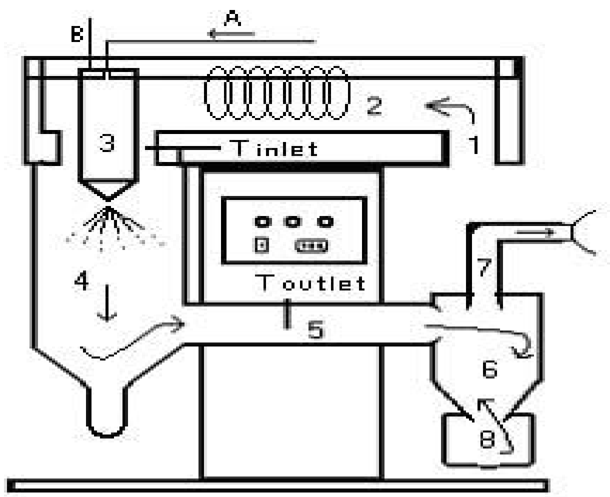

Figure 2.1: Laboratory scale spray dryer.

There are many types of dryer in our chemical environment and all the equipment are depend on the situation and the characteristic of the material that desired to dried. The freeze-dried product presented superior quality, but the spray-dried powder was stable and could be produced at a lower cost. When comparing vacuum and freeze-drying, the first method provided a better balance between product quality and production cost. 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. For that reason, this research is using spray drying in order to produce the best suitable condition of powder for good consumer.

2.3.1 Mechanism

Spray drying is a commonly used method of drying a liquid feed through a hot gas. Typically, this hot gas is air but sensitive materials such as pharmaceuticals and solvents like ethanol require oxygen-free drying and nitrogen gas is used instead. The liquid feed varies depending on the material being dried and is not limited to food or pharmaceutical products, and may be a solution, colloid or suspension. This process of drying is a one step rapid process and eliminates additional processing.

The liquid feed is pumped through an atomizer device that produces fine droplets into the main drying chamber. Atomizers vary with rotary, single fluid, two-fluid, and ultra-sonic nozzle designs. This type of spray nozzle utilizes high (20 kHz to 50 kHz) frequency vibration to produce nearly narrow drop size distribution and low velocity spray from a low viscosity liquid. The vibration of a piezoelectric crystal causes capillary waves on the nozzle surface liquid film. The primary factors influencing the drop size produced are frequency of vibration, surface tension and density of the liquid. These different styles have different advantages and disadvantages depending on the application of the spray drying required. In some instances a Spray Nozzle is used in place of an atomizer for a different dispersion rate. A nozzle is usually used to make the droplets as small as possible, maximizing heat transfer and the rate of water vaporization. Droplet sizes can range from 20 µm to 180 µm depending on the nozzle.

The hot drying gas can be passed as a co-current or counter-current flow to the atomizer direction. The co-current flow enables the particles to have a lower residence time within the system and the particle separator (typically a cyclone device) operates more efficiently. The counter-current flow method enables a greater residence time of the particles in the chamber and usually is paired with a fluidized bed system.

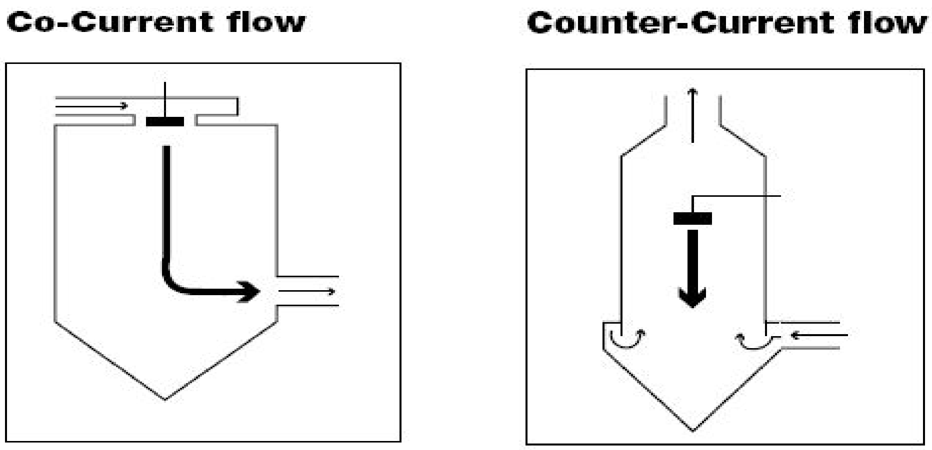

Figure 2.2: Flow of Hot Drying Air

Spray drying often is used as an encapsulation technique by the food and pharmaceutical industries. A substance to be encapsulated (the load) and an amphipathic carrier (usually some sort of modified starch) is homogenized as a suspension in water (the slurry). The slurry is then fed into a spray drier, usually a tower heated to temperatures well over the boiling point of water.

As the slurry enters the tower, it is atomized. Partly because of the high surface tension of water and partly because of the hydrophobic/hydrophilic interactions between the amphipathic carrier, the water, and the load, the atomized slurry forms micelles. The small size of the drops (averaging 100 micrometers in diameter) results in a relatively large surface area which dries quickly. As the water dries, the carrier forms a hardened shell around the load.

Load loss is usually a function of molecular weight. That is, lighter molecules tend to boil off in larger quantities at the processing temperatures. Loss is minimized industrially by spraying into taller towers. A larger volume of air has a lower average humidity as the process proceeds. By the osmosis principle, water will be encouraged by its difference in fugacities in the vapor and liquid phases to leave the micelles and enter the air. Therefore, the same percentage of water can be dried out of the particles at lower temperatures if larger towers are used.

The application of the spray drying encapsulation technique is to prepare "dehydrated" powders of substances which do not have any water to dehydrate. For example, instant drink mixes are spray dries of the various chemicals which make up the beverage. The technique was once used to remove water from food products; for instance, in the preparation of dehydrated milk. Because the milk was not being encapsulated and because spray drying causes thermal degradation, milk dehydration and similar processes have been replaced by other dehydration techniques. Skim milk powders are still widely produced using spray drying technology around the world, typically at high solids concentration for maximum drying efficiency. Thermal degradation of products can be overcome by using lower operating temperatures and larger chamber sizes for increased residence times.

Spray drying consists of the following unit operations:

- Pre-concentration of liquid (for more economic operation, since evaporation is expensive)
- Atomization (creation of droplets)
- Drying in stream of hot, dry gas (usually air)
- Separation of powder from moist gas
- Cooling
- Packaging of product

Relatively high temperatures are needed for spray drying operations. Heat damage to products is generally only slight, however, because of an evaporative cooling effect during the critical drying period and because the subsequent time of exposure of the dry materials to high temperatures may be only very short. The typical surface temperature of a particle during the constant drying period is 45-50 °C. For this reason, it is possible to spray dry some bacterial suspensions without destroying the organisms. The physical properties of the products are intimately associated with the powder structure generated during spray drying. It is possible to control many of the factors that influence powder structure in order to obtain the desired properties.

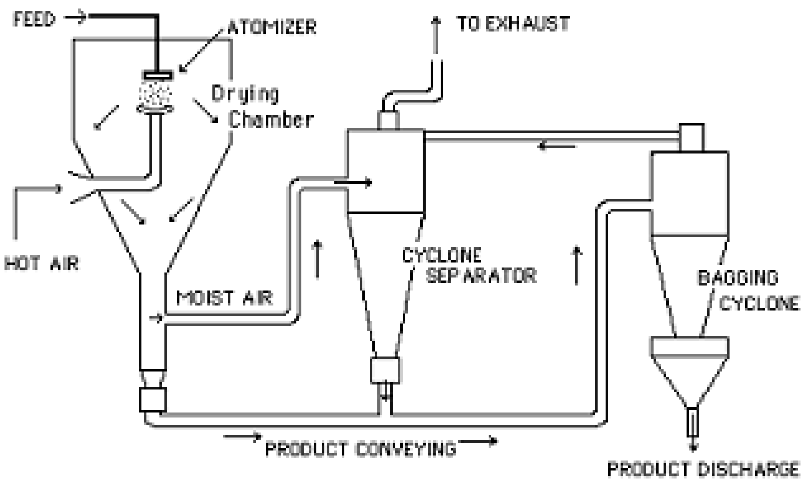

Figure 2.3: Overview of Spray Drying Process

The cyclone spray dryer is the most commonly used. Typically, a liquid product concentrate is pumped to the atomizing device where it is broken into small droplets. These droplets meet a stream of hot gas and lose moisture very rapidly while suspended in the drying air. The dry powder is separated from the moist air in cyclones by centrifugal action. The atomizer comprises either a spinning disc (rotating at 2000-20,000 rpm) or static high velocity jet nozzles.

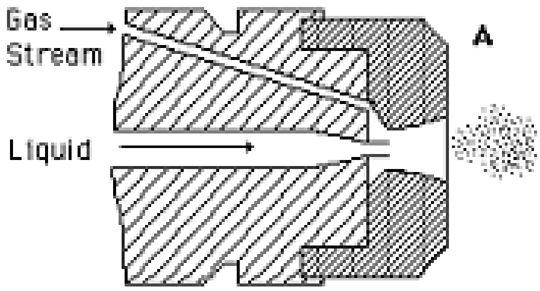

Figure 2.4: Atomizer of Spray Drying

Average operating conditions for spray drying vary depending on the application and on the dryer system used. These conditions must be adjusted to produce the desired uniform moisture content. The final moisture content and final particle size can be controlled by changing the operating conditions. Final moisture content is determined by the relative humidity of the outlet air and if that value is too high, powder particles will absorb rather than lose moisture.

The primary conditions which may be controlled directly by the operator are:

- Inlet temperature
- Flow rate of liquid feed (pump speed and pressure)
- Air flow rate
- Particle size (adjustment of atomizer)

Outlet temperature and relative humidity of the outlet air are also important, but can only be controlled indirectly through the adjustment of primary conditions.

From earlier there have been stated that atomizer is one of the main device in the spray drying. Actually atomization is of particular interest to the metal industry for generating fine powders. Generally it is carried out using an inert carrier gas. This gas forces molten powder (notably aluminium or solder) through a nozzle and then cools the droplets into highly spherical powders. The physics of gas atomization of metal powders involves multiphase gas flow, heat transfer, droplet formation, and solidification. Interaction between these individual mechanisms complicates understanding and modeling of the process. In addition, the chemical activity between some metals introduces further complexity. The challenge is to increase the powder yield, improve the powder quality and reduce the production cost. This requires both a thorough understanding of the process and a comprehensive experimental investigation in order to guide the design of the gas atomizer and to determine optimal settings of critical process variables.

Recent research is now suggesting that the use of spray-drying techniques may be an alternative method for crystallization of amorphous powders during the drying process since the temperature effects on the amorphous powders may be significant depending on drying residence times.

2.3.2 Research Studies

Spray drying is a process widely used to produce fruit juices powders([Abadio et al., 2004], [Cano-Chauca et al., 2005] and [Quek et al., 2007]). The physicochemical properties of powders produced by spray drying depend on some process variables, such as the characteristics of the liquid feed and the inlet air temperature, as well as the type of atomizer. Therefore, it is important to optimize the drying process, in order to obtain products with better sensory and nutritional characteristics and better process yield.

Some works have been carried out to study the behavior of soursop fruit during flow (Gratao et al, 2007). On the other hand, there is little information about drying of soursop pulp. The research only have been made using fluidized bed drying of soursop pulp (Telis et al.), and none of using spray drying. But there are several research studies on production of other fruit juice powder using spray drying. My main literature review for this study is production of Açai powder using spray drying.

2.3.2.1 Açai Powder (Renata et al, 2008)

The objective of this work was to study the influence of spray drying conditions on the physicochemical properties of açai powder. Maltodextrin 10DE was used as carrier agent in producing this powder. Independent variables that were study are inlet air temperature, feed flow rate and maltodextrin concentration. Moisture content, hygroscopicity, process yield and anthocyanin retention were analysed as responses. Powder moisture content and process yield were positively affected by inlet air temperature and negatively affected by feed flow rate, which are directly related to heat and mass transfer. Process yield was also negatively influenced by maltodextrin concentration, due to the increase on mixture viscosity. Powders hygroscopicity decreased with increasing maltodextrin concentration, decreasing temperature and increasing feed flow rate. Powders with lower moisture content were more hygroscopic, which is related to the greater water concentration gradient between the product and the surrounding air. Anthocyanin retention was only affected by temperature, due to its high sensitivity. In respect to morphology, the particles produced at higher temperature were larger and a great number of them showed smooth surface.

2.3.2.2 Mango Powder (Cano et al., 2005)

This work aimed the induction of crystallization on powder mango juice during the process of spray drying and the correlation of the microstructure of the powder obtained with the functional properties of stickiness and solubility. To perform this work, mango juice with 12 °Brix were used. Before being dehydrated, the juice undertook addition from the following carriers: maltodextrin, gum arabic and starch waxy in the concentration of 12%. The solution also received addition of crystalline cellulose in the concentrations of 0, 3, 6 and 9%. The powder was obtained through the use of a mini-spray dryer of laboratorial scale. Analyses of microstructure, stickiness, hygroscopicity and solubility were performed on the obtained powder. The microstructure analyses showed that the powders of the mango juices obtained through spray drying using the carrier's maltodextrin, gum arabic, starch waxy without the addition of cellulose presented surfaces of amorphous particles. The analysis XRD showed that when 3, 6 and 9% of cellulose were added, the particles showed half-crystalline surfaces. The value of stickiness decreased in terms of the concentration of cellulose reaching values of 0.15, 0.22 and 0.11 Kg-f for maltodextrin, gum arabic and starch waxy, respectively. The functional property of solubility is affected when 9% of cellulose is added reaching the values of 72, 71 and 31% for the carrier's maltodextrin, gum arabic and starch wax, respectively.

2.3.2.3 Orange powder (Chegini et al, 2007**)**

The first objective of this research were to build up and evaluate the predictive performance of an ANN model to approximate a nonlinear function relating five physical properties of orange juice powder as well as two process parameters of spray dryers to the three process parameters of feed flow rate, atomizer speed and inlet air temperature. Second objective was to evaluate the effects of the ANN parameters on model performance.

In this study, the effects of feed flow rate, inlet-air temperature, and atomizer speed, in an orange juice semi-industrial spray dryer, were studied on seven performance indices, namely: residual moisture content of orange juice powder, particles size, and bulk density, average time of wet ability, insoluble solids, outlet air temperature and dryer yield. A supervised artificial neural network (ANN) trained by back propagation algorithms was developed to predict seven performance indices based on the three input variables.

The numbers of patterns used in this study were 80, used for training, verification, and testing the neural networks. After evaluating a large number of trials with various ANN architectures, the optimal model was a four-layered back-propagation ANN, with 14 and 10 neurons in the first and the second hidden layers, respectively. The ANN technology had been shown to be a useful tool to investigate, approximate and predict the physical properties of orange juice powder as well as process parameters of spray dryers. The final selected ANN model was able to predict the seven output parameters with RMSE lower than 0.042, R2 higher than 0.93, and T value higher than 0.97. The results confirmed that the properly trained ANN model was able to produce simultaneously seven outputs, unlike traditional models where one mathematical model was required for each output. Radial Basis Function neural networks were not able well to learn the relationship between the input and output parameters. ANN parameters had a significant effect on learning ability of the ANN models.

2.3.2.4 Guava Powder (Chetan et al)

The first objective of this study was to select the correct enzyme dosage and optimum treatment time and temperature for maximizing yield of cloudy juice and retaining ascorbic acid. At the same time, the cost effectiveness of the enzymes utilized was also of interest. A second objective was to evaluate the effect of both ultra filtration and plate and frame filtration on the flux, turbidity, ascorbic acid retention and soluble solids (SS) content of clarified guava juice. The third objective was to prepare guava powders using freeze drying, spray drying and tunnel drying methods and evaluate the effects of drying on physicochemical properties. A consumer preference test was conducted to determine the sensory quality of these clarified juice, cloudy juice and reconstituted juice products, and to compare products to those available in the market.

As my research was about spray drying, so I take spray drying of guava powders as my first priority. Guava juice concentrate and diluted aseptic guava puree were spray dried using an APV Anhydro A/S laboratory size no.1 spray dryer (Attleboro, MA). A Bosch 1210 type atomizer (Scintilla SA, Switzerland) with the atomizer speed regulator set at 220 volts was utilized. The inlet temperature of the feed material was set to 160°C by adjusting the power supply with a 5 kW heating element. The outlet (product) temperature was set to 80°C by regulating the feed pump speed. Powder was separated from hot air by a cyclone separator and stored at room temperature. Three different maltodextrin products, Maltrin 100®, Maltrin 500® and Maltrin 580®, were added to the samples prior to spray drying.

The following combinations were selected and blended using a hand mixer prior to drying:

i. 300 g clear juice concentrate + 285 g Maltrin 100®
ii. 300 g clear juice concentrate + 285 g Maltrin 500®
iii. 3000 g 4.7°Brix puree + 249 g Maltrin 580® + 48 g Maltrin 100® + 13 g Maltrin 500®

The freeze-dried product had superior quality; however the spray-dried product was stable and may be more economical. Sensory panelists ranked the cloudy juice prepared from aseptic guava puree highest, and there were no significant differences between the juices from pasteurized, clear nectar, freeze-dried puree powder or juice powder.

2.3.2.5 Watermelon Powder (Quek et al., 2007)

Watermelon is a seasonal fruit and it is not available all year round. Because of its high nutritional value, it is beneficial if a watermelon product can be produced and make available throughout the year. Spray drying can be applied to turn the watermelon juice into powder that has longer shelf life and is readily available. Ideally, the spray-dried watermelon powder should have instant properties or served as a source of lycopenerich functional food ingredient for addition into food products. Up-to-date, the main dietary lycopene source is from tomato, so the development of lycopene-rich watermelon powder will provide the consumers with alternative choice. There are considerably substantial amount of works on spray drying of fruit juice up-to-date. However, there have been limited scientific literatures concerning drying of watermelon juice. Based on the above reasons, this study is undertaken to investigate the feasibility of spray drying of watermelon juice and to evaluate the physicochemical properties of the powder produced, including the content of lycopene, carotene, moisture, water activity, dissolution and colour.

2.4 Physical Properties

Foods to be spray dried can be subjectively classified into two broad groups: non-sticky and sticky. In general, non-sticky materials can be dried using a simple dryer design and the final products remain free flowing. Materials such as skim milk and solutions such as maltodextrins, gums, and proteins belong to this group. On the other hand, sticky materials are difficult to dry under normal spray drying conditions. Natural sugar and acid-rich foods such as fruit and vegetable juices, and honey belong to this group. The sticky behavior of sugar and acid-rich materials is attributed to low molecular weight sugars such as fructose, glucose, sucrose and organic acids such as citric, malic and tartaric acid which constitute more than 90% of the solids in fruit juices and purees (Dolinsky et al, 2000).

Fruit juice powders obtained by spray drying may have some problems in their properties, such as hygroscopicity and solubility, due to the presence of low molecular weight sugars and acids, which have low glass transition temperature (Bhandari et al., 1993). Thus they can stick on the dryer chamber wall during drying, leading to low product yield and operational problems. From this theory, we can conclude that stickiness is a major reason which has limited the use of spray drying for sugar-rich and acid rich foods. Part of these problems can be solved by the addition of some carrier agents, like polymers and gums, to the product before being atomized. In this research, maltodextrin is being use. Several types of additives also can protect sensitive food components against unfavorable ambient conditions, mask or preserve flavors and aromas, reduce the volatility and reactivity and provide additional attractiveness for the merchandising of food products.

2.4.1 Carrier Agent

Maltodextrin is classified as a complex carbohydrate, but acts like a simple carbohydrate in the body. Because of this reason, maltodextrin will not supply long-lasting energy provided by most complex carbohydrates. Maltodextrin is a synthetically manufactured long chain carbohydrate. Also known as a polysaccharide (many sugars), maltodextrin is artificially created when acids or other enzymes are applied to cornstarch, which breaks the starch into medium-length chains of dextrose (glucose) molecules. Simply put, maltodextrin is a very long chain of repeating glucose molecules connected together. Because of this particular structure, maltodextrin can be classified as a complex carbohydrate, as opposed to a simple carbohydrate like glucose. Maltodextrin may be disguised on labels with different names; sometimes it is referred to as “glucose polymers” or complex carbohydrate. Maltodextrin is easily digestible, being absorbed as rapidly as glucose, and might either be moderately sweet or might have hardly any flavor at all. It is produced from starch and is usually found as a creamy-white hygroscopic powder. Maltodextrin can be derived from any starch. In the US, this starch is usually rice, corn or potato; elsewhere, such as in Europe, it is commonly wheat. This is important for coeliacs, since the wheat-derived maltodextrin can contain traces of gluten. There have been recent reports of coeliac reaction to maltodextrin in the United States. This might be a consequence of the shift of corn to ethanol production and its replacement with wheat in the formulation.

Simple carbohydrates are typically singular or up to three sugar molecules in length. Maltodextrins can be hundreds of sugar molecules in length, much larger than the simple carbohydrate arrangement of glucose. Because of this, many beverages include maltodextrin in their formulas in order to have a lower amount of sugar on their nutrition fact label. Maltodextrin, classified as a complex carbohydrate, will be included under the “Total Carbohydrate” heading on the nutrition label, rather than under the ‘sugars’ label. Once maltodextrin is digested, it becomes glucose.

While complex carbohydrates such as maltodextrin can be beneficial prior to and following exercise, they must be altered by the body prior to direct usage in energy processes because of their large size. Maltodextrin is very different from a typical complex carbohydrate because of its simplified structure of repeating dextrose units. It does not provide the long-term energy that a true complex carbohydrate does. Maltodextrin must first be enzymatically altered by the body before its benefits are realized in the form of energy.

Naturally occurring complex carbohydrates often contain some vitamins and minerals that are required to assist assimilation of the carbohydrate into the body’s energy processes. In one sense, nature packages them this way, so that the complex carbohydrates bring their own digestive and energy cofactors with them, into the body. Conversely, maltodextrin typically contains very little, if any vitamins and minerals to assist with its own digestion and assimilation. Because of this, consuming maltodextrin may actually reduce the amount of vitamins and minerals in the body. Due to the large size of maltodextrin, it uses more vitamins and minerals than will a simple carbohydrate, which can lead to a net decrease in an athlete’s vitamin and mineral status over time.

2.4.2 How Maltodextrin is made

As a rather common additive to a number of different types of foods, maltodextrin is classified as a sweet polysaccharide. While containing sweet qualities, maltodextrin is considered to contain fewer calories than sugar. Here are some examples of how maltodextrin is made from natural foods, as well as how maltodextrin can be used in a number of recipes.

While considered to be a carbohydrate, maltodextrin is understood to be more easily digested than some other forms of carbohydrates, leaving behind less of the potential for health issues. This can be especially important for an individual who is trying to manage their Type 2 diabetes with their diet. Usually made from rice, corn, or potato starch, maltodextrin is produced by cooking down the starch. During the cooking process, this is often referred to as a hydrolysis of starch, natural enzymes and acids help to break down the starch even further. The end result is a simple white powder that contains roughly four calories per gram, and extremely small amounts of fiber, fat, and protein.

Around the kitchen, maltodextrin is among some of the most usable of the dextrin family. At least one of the major artificial sweeteners relies on a base of maltodextrin. This means the substance can often be found in packaged goods such as instant pudding and flavored gelatins. The sweet taste of maltodextrin makes is a closer approximation to the taste of sugar, which makes it ideal for use in sweetening teas, coffee, and powdered soft drinks. Maltodextrin can also be used as a thickening agent in a number of sauces and salad dressings.

While there is some amount of uneasiness with just about any type of food additive, it is important to remember that maltodextrin is an example of dextrin products that are derived from a natural source. While maltodextrin is a processed additive, the natural basis for the product helps to make it easier for the body to digest than many other forms of sugar substitutes.

Also, anyone who wants to watch their intake of carbohydrates or sugar will find that maltodextrin is a very helpful substance to have around the house. Whether using maltodextrin to sweeten liquids, or to help thicken a broth or gravy for a casserole, or just as a way to add a little sweetness without the calories, maltodextrin is an inexpensive and safe way to get the taste you want. As a bonus, you can have the sweet taste and not have to be concerned about many of the health risks associated with artificial sweeteners.

2.4.3 Maltodextrin 10DE

For this research, maltodextrin 10DE was used as the carrier agent of spray drying process. Our supplier for this type of maltodextrin was San Soon Seng Food Industries Sdn Bhd (SSSFI). This company is located at AL 308, Lot 590 & Lot 4196, Jalan Industri, U19, Kampung Baru Seri Sungai Buloh, Selangor Darul Ehsan. Actually SSSFI Maltodextrin is Non-GMO tapioca based products line; cover the dextrose equivalent (DE) range from 10 to 40. Each product differs in its degree of hydrolysis, providing wide range of functionalities and properties for special applications. Maltodextrin often use as bulking agent, dispersant, carrier, binding agent, processing aid and texture improver in a variety of food and beverage products. Below is the specification of maltodextrin that we used.

Table 2.2: Properties of Maltodextrin

SPECIFICATION:

1) Dextrose Equivalent	9 - 12
2) Moisture, %	Max. 5.0
3) pH (20% Solution)	4.5 - 5.5
4) Sulphur Dioxide, ppm	Max. 10
5) Colour (O.D.)	Max. 2.0
6) Bulk Density (tapped), g/l	450 - 600

MICROBIOLOGICAL DATA:

1) Total Plate Count, cfu/g	< 1000
2) Total Yeast Count, cfu/g	< 50
3) Total Mould Count, cfu/g	< 50

Shelf Life	2 years
Raw Material	Non-GMO Tapioca Starch
Storage Condition	Cool & dry condition

PACKING: 25 kg Kraft Paper Bag with PE Inner Liner

CHAPTER 3

METHODOLOGY

3.1 Introduction

This study was about food engineering and because of that, every single materials and equipment that being using was not hazardous. Very little precaution only needs to be considering in doing all the experiment. But this is not the licenses to do the experiment with not full hearted. Every single method in this research was based on reasonable journal that can be references.

3.2 Equipments/ Apparatus

In completing the study, some equipment is required. There are:

1. Laboratory Scale Spray Dryer Unit (SD-06)
2. Oven (Memmert)
3. Vacuum Oven (Fisher)

4. Electric Blender
5. Electric Balance Shimadzu (A W220)
6. Refrigerated Centrifuge (5810 R)
7. Hot Plate and Magnetic Stirrer (ERIA)
8. Centrifuge tube 50ml and 25ml
9. Beaker
10. Micro Pipette
11. Aluminium Weighing Boat
12. Filter Paper
13. Syringe
14. Dropper
15. Muslin Cloth
16. Tray

3.3 Collection of Fruits

Raw materials that be used are not available in FKKSA laboratory and because of that several problems occur in getting the raw materials. Even though the raw materials in this study is only soursop fruits, but the problems occur is huger that other Under Graduate Project (URP) students since the soursop fruits are difficult to find.

As indicate before, soursop has a lot of benefits. One of it, is the ability of itself for commercializes. Every single good thing in this world has their valuable prices to get. Same goes to my lovely soursop. I'm not very sure about the peak time of harvesting of soursop in Malaysia. Different country will have different time of harvesting soursop. By that reason, there are very difficult for me to get soursop fruits. I wandered through markets looking for them without much luck. I came across some, but they were so blackened that wondered if they were overripe or even rotten and couldn't bring myself to but one. But after a few days being searching, lastly I found and bought some soursop fruits from one of fruits stall in Benteng, Kuantan. The soursop is not fully riped because soursops have to be harvest from tree before its riped in order to maintain the freshness of the pulp itself. Soursops have to be keeping a few days before it ready to being converted to juices.

3.4 Preparation of soursop juice

The fruits were washed under running tap water, hand peeled, decored, deseeded and the pulp blended using an electric blender. Water was added in the ratio of 1:2 (w/v, pulp/water) to facilitate the blending process and it was repeated twice to achieve a smooth-textured puree. The pulp was filtered using a muslin cloth. Soursop pulp is actually full of fibrous. So that, in order to run the experiment smoothly, the pulp and fibrous must be separated physically. There is several method of separation that can be applied. But in this experiment I prefer to use centrifuge because the taste and texture of juices still maintained. The centrifuge that has been use is refrigerated centrifuge 5810 R Eppendorf. Speed of the centrifuge was set to 5000rpm and temperature 4^{0}C. Separation process was done for only 5 minutes for each juices sample due to maintain some of the solid content in the juices texture.

Once the juice total solids were standardized, the following substances were added: maltodextrin 10 DE (dextrose equivalent) from San Soon Seng Food Industries Sdn. Bhd. (SSSFI). This type of maltodextrin is Non-GMO tapioca based products line. Maltodextrin often use as bulking agent, dispersant, carrier, binding agent, processing aid and texture improver in a variety of food and beverage products. The mixtures were stirrer well by hot plate stirrer using magnetic stirrer. Maltodextrin was added according to the weight of the soursop juice. For every trial, 300ml of soursop juices were needed. Concentration of maltodextrin that were being study is 10%, 15%, 20% and 25%. So for each percentage, 30g, 45g, 60g and 75g of maltodextrin were added in order to get the exact concentration of maltodextrin. The calculation is as followed:

This method is more convenient to use when the solute is in solid phase.

% mass/volume (%w/v)

- % of mass of solute in gram per volume of solution in ml

% w/v = [mass of solute (gram) / volume of solution (ml)] x 100%

Example:

20% of maltodextrin in 300ml of juice

20% = (mass of maltodextrin / 300ml) x 100%

= 60g

3.5 Obtaining Powders by Spray Drying

Figure 3.1: Laboratory Scale Spray Dryer Unit (SD-06)

After juices have been added with maltodextrin, it is ready to being sprayed. Spray drying process is performed in a laboratory scale spray dryer unit (SD-06) with a 1.5mm diameter nozzle and main spray chamber of 500mm x 215mm. The mixture is fed into the main chamber through a peristaltic pump and the feed flow rate was controlled by the pump rotation speed. Drying air flow rate was $73m^3/h$ and compressor air pressure was 0.06 MPa. Four inlet air temperatures were investigated in this research. There were 160^0C, 170^0C, 180^0C and 190^0C. Spray drying was carried out at the aspirator rate (fan setting) of 15L/h, flow rate (pump setting) of 600 L/h, pressure of 4.5 bars, and feed temperature of 20^0C. These conditions were chosen after conducting initial trial runs and were kept constant for every sample that being used. The feed was pulverized in a nozzle with a co-current airflow produced by a blower. Every 300ml of juices will take about two hours to complete the drying process. The dryer was washed with water at the parameter setting as same as conducting the juices for 10 min before and after the spray drying process. All the spray-dried powders were collected in clean water activity container with known weight. The powders produced were weighed, placed into commercial bags (approximately 100 g) and stored at 4 ^0C in dark until analyses.

Figure 3.2: Soursop Powder

3.6 Experimental Procedure

In this research, feed mixtures that are *Annona Muricata* juices are analyze for its moisture content. While for spray dried juices powder, they are analyses for moisture content, hygroscopicity, dissolution and solubility. Moreover, the juices powder produced with different maltodextrin concentrations and at different inlet air temperature are also analyses in respect to process yield. Sensory evaluation test also must be done to produce suitable product for consumer. All analytical measurements were carried out in triplicate for accurate results.

3.6.1 Moisture Content

Moisture content is one of the most commonly measured properties of food materials. It is important to food scientists for a number of different reasons:

- **Legal and Labeling Requirements.** There are legal limits to the maximum or minimum amount of water that must be present in certain types of food.
- **Economic.** The cost of many foods depends on the amount of water they contain. As we know water is an inexpensive ingredient, and manufacturers often try to incorporate as much as possible in a food, without exceeding some maximum legal requirement.
- **Microbial Stability.** The propensity of microorganisms to grow in foods depends on their water content. For this reason many foods are dried below some critical moisture content.
- **Food Quality.** The texture, taste, appearance and stability of foods depend on the amount of water they contain.
- **Food Processing Operations.** Knowledge of the moisture content is often necessary to predict the behavior of foods during processing such as mixing, drying, flow through a pipe or packaging.

It is therefore important for food scientists to be able to reliably measure moisture contents. A number of analytical techniques have been developed for this purpose, which vary in their accuracy, cost, speed, sensitivity, specificity, ease of operation, and other more. The choice of an analytical procedure for a particular application depends on the nature of the food being analyzed and the reason the information is needed.

Testing methods for moisture content include either a vacuum or mechanical convection oven, or the toluene distillation method. The objective of the test is to determine the volume of available of “free” moisture. Too high of a moisture content can contribute to unwanted microbiological growth or the Maillard reaction browning. The toluene distillation method is very reproducible but it also measures the water of crystallization. This “bound” water is not available for microbiological growth so it is not a factor in determining the quality of the powder.

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

Weighed samples are placed under reduced pressure (typically 25-100 mm Hg) in a vacuum oven for a specified time and temperature and their dried mass is determined. The thermal energy used to evaporate the water is applied directly to the sample via the metallic shelf that it sits upon. There is an air inlet and outlet to carry the moisture lost from the sample out of the vacuum oven, which prevents the accumulation of moisture within the oven. The boiling point of water is reduced when it is placed under vacuum. Drying foods in a vacuum oven therefore has a number of advantages over conventional oven drying techniques. If the sample is heated at the same temperature, drying can be carried out much quicker. Alternatively, lower temperatures can be used to remove the moisture (e.g. 70^0C instead of 100 ^{0}C), and so problems associated with degradation of heat labile substances can be reduced.

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

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

Here, $M_{INITIAL}$ and M_{DRIED} are the mass of the sample before and after drying, respectively. The basic principle of this technique is that water has a lower boiling point than the other major components within foods, e.g., lipids, proteins, carbohydrates and minerals.

3.6.2 Hygroscopicity

Hygroscopy is the ability of a substance to attract water molecules from the surrounding environment through either absorption or adsorption. Hygroscopic substances include honey, glycerol, ethanol, methanol, concentrated sulfuric acid, methamphetamine, iodine, and concentrated sodium hydroxide (lye). Because of their affinity for atmospheric moisture, hygroscopic materials may need to be stored in sealed containers.

Hygroscopicity is a measure of water absorption by a powder. It is often measured by passing air of a known humidity level (usually 80% at 20^0C) over a powder until equilibrium is reached, then measuring the weight gain. Powders which absorb a lot of moisture may cake during storage, although there is no direct relationship between hygroscopicity and tendency to cake as other factors are involved as well.

Hygroscopicity was determined according to the method proposed by (Cai and Corke, 2000). But some modifications have been made. Samples of 0.5g each powder were weight in aluminums weighing boat and will placed in a container that set to room temperature with NaCl saturated solution. After two week, samples were weighed and hygroscopicity was expressed as below.

$$\% \text{ Hygroscopicity} = \frac{\text{weight of moisture absorb (g)}}{\text{Weight of sample (g)}} \times 100\%$$

3.6.3 Dissolution Test

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

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

3.6.4 Solubility

Solubility is an important feature of powders. Poorly soluble powders can cause processing difficulties and can result in economic losses as total solids content of juice may be lost as insoluble material. Solubility is often seen as a property of a substance; for instance the solubility of a solid substance usually refers to the concentration of the substance in a liquid that has reached equilibrium with the substance in solid phase. The solubility of a solute is the maximum quantity of solute that can dissolve in a certain quantity of solvent or quantity of solution at a specified temperature. The main factor that has an effect on solubility is:

- Temperature - Generally, an increase in the temperature of the solution increases the solubility of a solid solute. A few solid solutes, however, are less soluble in warmer solutions.

The solubility was determined by homogenization, centrifugation and determination of the insoluble residue from the dissolution of powdered juice in distilled water. Actually in this research, solubility was determined according to the (Eastman and Moore method, 1984), with some modifications. 100mL of distilled water is transferred into 250ml beaker. The powder sample (1g, dry basis) is carefully added into the beaker and was homogenize by using hot plate stirrer and will be operating at high velocity for 5 min. The solution then was placed in tube and centrifuged at 3000rpm during 5 min. An aliquot of 25 ml of the supernatant was transferred to pre-weighed Petri dishes and immediately oven-dried at 105 °C for 5 h. Then the solubility (%) was calculated by weight difference.

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

3.6.5 Process Yield

In order to obtain the best process yield of powders, we have to make several tests for inlet air temperature and maltodextrin concentration. The actual inlet air temperature will be displayed at all times on the set temperature screen on spray dryer equipment. Thus tests will be repeated using different various temperatures that will be set before produce powder. There were 160^0C, 170^0C, 180^0C and 190^0C respectively. While for maltodextrin, it will be added to *Annona muricata* juices under magnetic agitation, until complete dissolution. Concentration of maltodextrin that were being study is 10%, 15%, 20% and 25%. So for each percentage, 30g, 45g, 60g and 75g of maltodextrin were added in order to get the exact concentration of maltodextrin.

This method will be done for several tests until the best maltodextrin concentration in producing powder that have highest process yield was obtained. Process yield was calculated as the relationship between total solids content in the resulting powder and total solids content in the feed mixture. Total solid content can be measure using refractometer. Sometimes the total solids content is reported as a measure of the moisture content using evaporation methods. The total solids content is a measure of the amount of material remaining after all the water has been evaporated:

$$\%\text{Total Solids} = \frac{M_{\text{DRIED}}}{M_{\text{INITIAL}}} \times 100$$

Thus, %Total solids = (100 - %Moisture). To obtain an accurate measurement of the total solids of a food using evaporation methods it is necessary to remove all of the water molecules that were originally present in the food, without changing the mass of the food matrix. This is often extremely difficult to achieve in practice because the high temperatures or long times required to remove all of the water molecules would lead to changes in the mass of the food matrix, e.g., due to volatilization or chemical changes of some components.

EXPERIMENT FLOW CHART

Soursops fruits are buy from nearest market

↓

Soursop is hand peeled, decored, deseeded and the pulp blended to make juices.

↓

The juices were filtered and added with different concentration of maltodextrin.

↓

Initial sample are collected to measure moisture content for each different maltodextrin and were spray dried in the different inlet air temperature.

↓

The powder produced tested for its moisture content, hygroscopicity, dissolution and solubility.

↓

The best inlet air temperature and maltodextrin concentration due to its dryer yield is identified.

Figure 3.3: Schematic diagram for the process to convert soursop juice to powder.

CHAPTER 4

RESULTS AND DISCUSSIONS

As stated before, there are two main objectives in this research. First objective is to produce soursop juice powders using spray drying. While second objective is to determine the optimum condition for spray drying soursop juice. The first objective was achieved ones soursop juice powders was obtained. But for the second objective, some analysis of certain response must be carried out in order to determine the optimum condition for spray drying. The optimum conditions consists of inlet air temperature that use for spray drying and concentration of maltodextrin that should be added to soursop juice before being spray dried. The optimum conditions are important because it will give the best properties of soursop juice powder and at the same time having high value for commercialize.

4.1 Process Yield

Process yield was calculated as the relationship between total solids content in the resulting powder and total solids content in the feed mixture. The total solids content is reported as a measure of the moisture content using evaporation methods. Actually, the total solids content is a measure of the amount of material remaining after all the water has been evaporated. So in this research, total solid content is calculated based on moisture content percentage as mention earlier in chapter 3.

Table 4.1: Process Yield Obtained of The Spray Dried Powders.

Inlet Air Temperature(^{0}C)	Total Solid Content Feed Mixtures (%)	Total Solid Content Powders (%)	Maltodextrin Addition (%)	Process Yield (%) (Total Solid Content Powders – Total Solid Content Feed Mixtures)
160	26.892	99.977	10	71.285
	29.978	99.979	15	70.001
	32.625	99.978	20	67.353
	35.307	99.592	25	64.285
170	26.892	99.986	10	71.294
	29.978	99.984	15	70.006
	32.625	99.980	20	67.355
	35.307	99.983	25	64.676
180	26.892	99.744	10	71.052
	29.978	99.968	15	69.990
	32.625	99.743	20	67.118
	35.307	99.974	25	64.667
190	26.892	99.923	10	71.231
	29.978	99.923	15	69.945
	32.625	99.872	20	67.247
	35.307	99.768	25	35.307

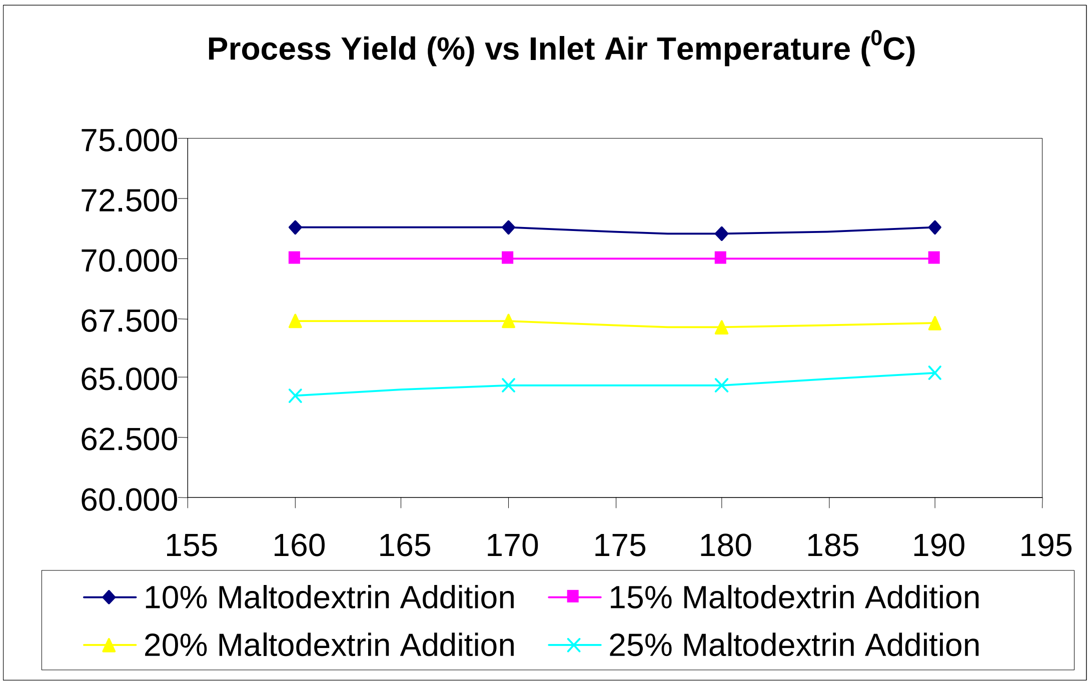

Figure 4.1: The Effect of Inlet Air Temperature and Maltodextrin Addition on Process Yield.

As indicated in this research, inlet air temperature and maltodextrin concentration are both have significantly influenced on the spray drying process yield. Increasing temperatures led to higher process yield, which can be attributed to the greater efficiency of heat and mass transfer processes occurring when higher inlet air temperatures are used. This is in agreement with the results published by Cai and Corke (2000), working with spray drying of Amaranthus betacyanin pigments. While for the maltodextrin concentration, there will be a negative effect on process yield, probably due to the mixture viscosity, which exponentially increased with this variable. The increase on feed viscosity can cause more solids to paste in the main chamber wall, thus reducing the process yield (Cai and Corke et al, 2000). In addition, the higher the solids content in the mixture, the higher the amount of solids available to be in contact with the chamber wall and to paste in it. Thus, lower the process yield.

From the result obtain (Figure 4.1) we can observe that among the range of inlet air temperature with 10% maltodextrin addition will give the highest process yield of soursop juice powder produce. These results showed that maltodextrin was a useful drying aid in spray drying of soursop juice as it improved the yield of product. Maltodextrin used in this study was a low dextrose equivalent (DE) maltodextrin with DE of 10. Other researchers have reported that low DE maltodextrin has better nutrient binding properties. Maltodextrin is also proved to be a very good encapsulated for low molecular weight sugars such as fructose and organic acids. It was observed that with the addition of maltodextrin, the condition was improved. Addition of maltodextrin could increase the total solid content in the feed and thus, reduce the moisture content of the product. It was suggested that maltodextrin could alter the surface stickiness of low molecular weight sugars such as glucose, sucrose and fructose and organic acids, therefore, facilitated drying and reduced the stickiness of the spray-dried product. However, if the added maltodextrin was more than 10%, the resulted powders lost their taste. So from this analysis we can state that, 10% is the best percentage of maltodextrin addition in order to spray dried soursop juice. 10% means ten percent of total feed solution.

Table 4.2: Process Yield Obtained of the Spray Dried Powders with 10% Maltodextrin Addition.

Inlet Air Temperature(^{0}C)	Process Yield (%)
160	71.285
170	71.294
180	71.052
190	71.231

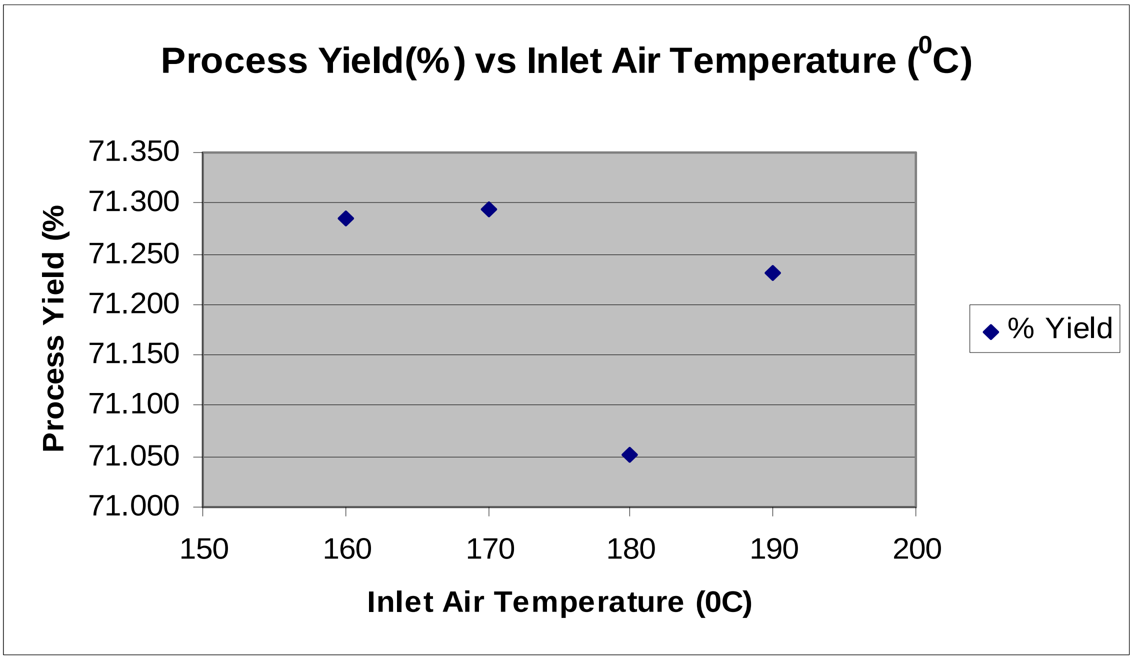

Figure 4.2: The Effect of Inlet Air Temperature with 10% Maltodextrin Addition on Process Yield.

As we can see from the Figure 4.2 170^{0}C gives the higher value of process yield, but when the temperature increase to 180^{0}C and 190^{0}C the result of process yield were not followed the agreement of powder that being study before this. That is increasing temperatures led to higher process yield, which can be attributed to the greater efficiency of heat and mass transfer processes occurring when higher inlet air temperatures are used. This behavior maybe related to the properties of soursop juice itself. The rheological properties of most of liquid foods exhibit substantial changes during the processing stages because of their dependence upon temperature and concentration. (Gratao et al, 2007). So because of this reason, the best temperature for process yield analysis was 170^{0}C.

4.1.1 Feed Moisture Content Powders Moisture Content

Table 4.3: Moisture Content Analysis Results of the Feed Mixtures.

Maltodextrin Addition (%)	Moisture Content (%)
10	73.108
15	70.022
20	67.375
25	64.693

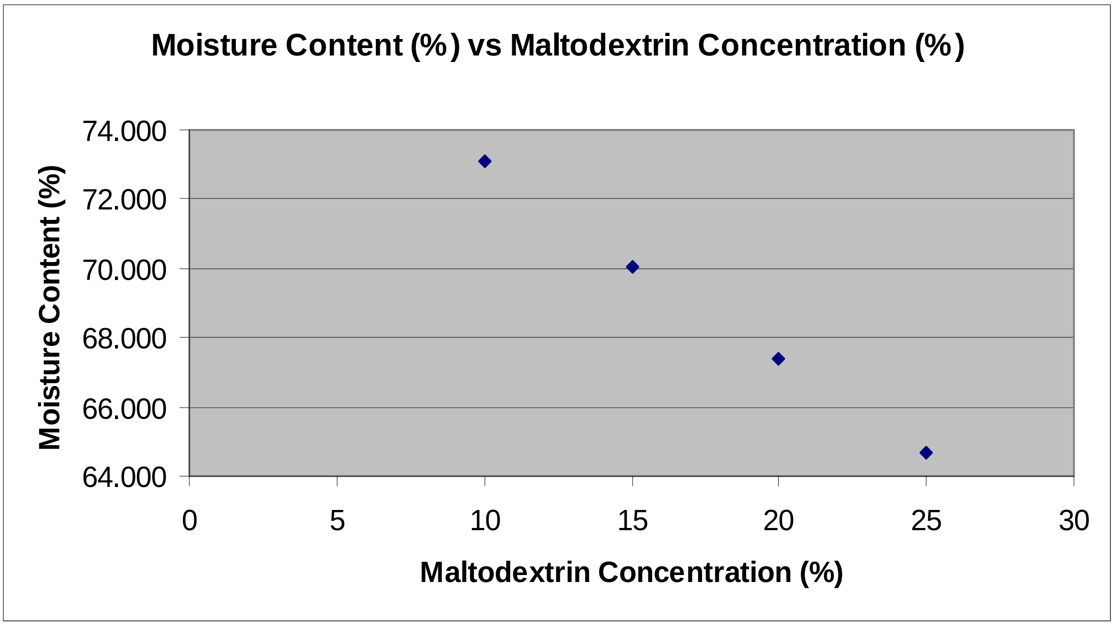

Figure 4.3: The Effect of Inlet Air Temperature on Moisture Content of Feed Mixtures.

4.2 Powders Moisture Content

For next analysis, 10% of maltodextrin addition was use as the dependent parameter. Moisture content was significantly influenced by inlet air temperature and feed flow rate. At higher inlet air temperatures, there is a greater temperature gradient between the atomized feed and the drying air, resulting in a greater driving force for water evaporation and thus producing powders with lower moisture content. (Quek et al. 2007) and (Rattes et al. 2007) and (also observed a reduction of powders moisture content with increasing air temperatures, in studying the spray drying of watermelon juice, sodium diclofenac and sweet potato puree. The powders moisture content increased with increasing pump rate and with decreasing inlet air temperature but the effect of temperature was greater than the effect of pump rate.

Maltodextrin Addition =10%

Table 4.4: Moisture Content Analysis Results of the Spray Dried Powders

Inlet Air Temperature(0C)	Moisture Content (%)
160	0.0228
170	0.0145
180	0.2559
190	0.0767

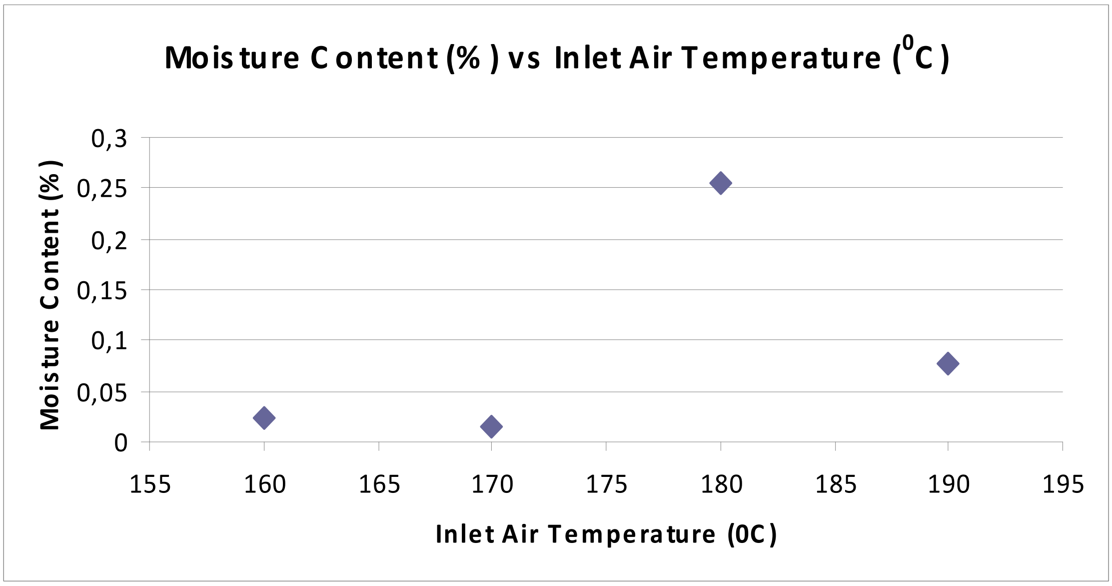

Figure 4.4: The Effect of Inlet Air Temperature on Moisture Content of Spray-Dried Powders.

All of the drying conditions reduced the moisture content of the powder. Powders moisture content varied from 0.0145% to 0.2559%. The results supposedly showed that at constant feed flow rate, the moisture content of the spray-dried powders decreased with the increased in inlet and outlet air temperature. This is because at higher inlet temperature, the rate of heat transfer to the particle is greater, providing greater driving force for moisture evaporation.

Consequently, powders with reduced moisture content are formed. The results were consistent with other funding (Gaula et al. 2004). Higher inlet drying air temperatures often resulted in decreased moisture content. This trend may be difficult to discern in this experimental design. Because of that, the results that obtained in this research are different because of soursop properties itself. Soursop is actually full of fibrous that are difficult to being separated. So the soursop juices still have some amounts of fibrous that are not fully being separated. This fibrous at the same time gives the juices powders the taste of soursop. When there are more fibrous in the feed mixtures that are our juices, total solid content of it will increase. As mention earlier, total solid content have relationship with moisture content. So from the result we can see, when the temperature increase to temperature more than $170^{0}C$ the moisture content will increase due to the morphological changes of sousop. Furthermore sprays drying were difficult due to high sucrose content and burn-on the equipment resulting from the high temperatures used. So we will consider the $170^{0}C$ is the optimum inlet air temperature for moisture content analysis.

4.3 Powders Hygroscopicity

Maltodextrin concentration was the variable that most affected powders hygroscopicity. The lowest hygroscopicity values were obtained when the highest maltodextrin concentrations were used. This is due to the fact that maltodextrin is a material with low hygroscopicity, and confirms its efficiency as a carrier agent. (Rodríguez-Hernández et al. 2005), working with spray drying of cactus pear juice, and Cai and Corke (2000), working with spray drying of betacyanin pigments, also verified a reduction of hygroscopicity with increasing maltodextrin concentrations.

This indicates that the lower the particles moisture content, the higher their hygroscopicity, i.e., the greater their capacity to adsorb ambient moisture, which is related to the greater water concentration gradient between the product and the surrounding air. These results are in agreement with those published by (Goula et al. 2004), in their work about spray drying of tomato pulp. Constantly the compressed air flow rate, the drying air flow rate and varying the inlet air temperature, the authors verified that powders hygroscopicity inversely increased with powders moisture content.

Maltodextrin Concentration = 10%

Table 4.5: Hygroscopicity Analysis Results of the Spray Dried Powders

Inlet Air Temperature(^{0}C)	Hygroscopicity (%)
160	12.775
170	8.532
180	9.452
190	14.763

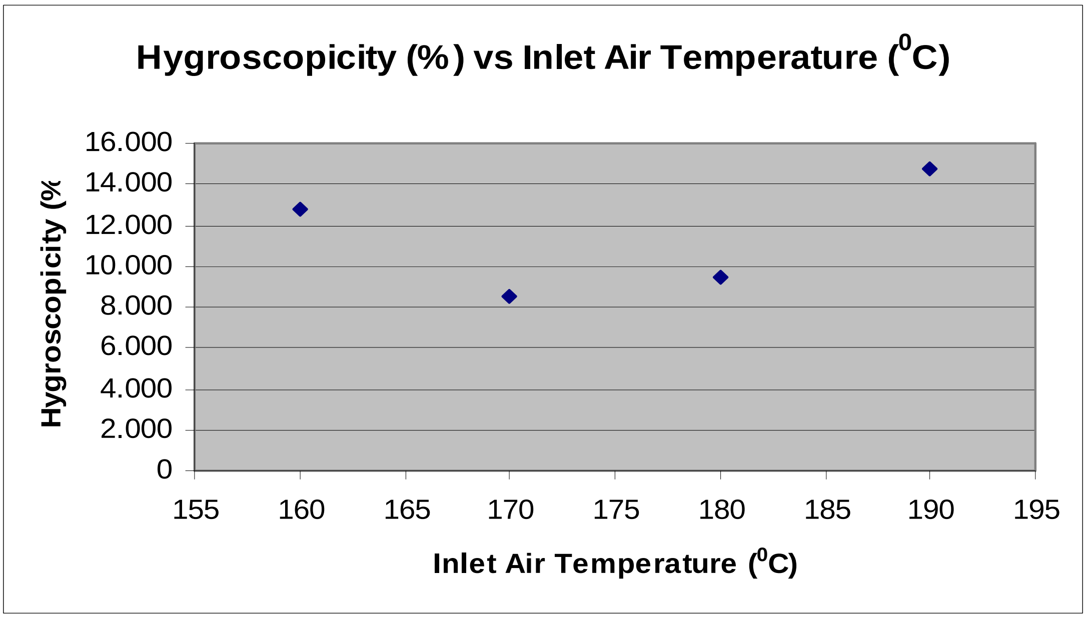

Figure 4.5: The Effect of Inlet Air Temperature on Hygroscopicity of Spray-Dried Powders.

Powders with lower hygroscopicity are in good quality as their shelf life is more than others powders with higher hygroscopicity. This is due to moisture that can be absorbed by the powders from surrounding. So the optimum inlet air temperature for this analysis is 170^{0}C with a lower hygroscopicity.

4.4 Powders Solubility

Solubility is the instant properties of a powder involve the ability of a powder to dissolve in water. Most powdered foods are intended for rehydration; therefore, the ideal powder would wet quickly and thoroughly, sink rather than float, and disperse or dissolve without lumps (Hogekampand et al. 2003). Conversely, adding maltodextrin reduced the water-holding capacity of the soursop powders. These effects of maltodextrin can be attributable to the inverse relationship between the maltodextrin concentration and the total solid content of powders itself. The changes in surface stickiness reduce the particle-particle cohesion and particle wall adhesion during spray-drying, resulting in less agglomerate formation and, therefore, lower water-holding capacity of the powders. Overall, however, all powders were only able to hold less than 3 times their weight in water, regardless of treatment (Grabowski et al. 2006).

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, soursop 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 soursop 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 soursop juice 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.

Maltodextrin Concentration = 10%

Table 4.6: Solubility Analysis Results of the Spray Dried Powders

Inlet Air Temperature(^{0}C)	Solubility (%)
160	77.910
170	78.499
180	77.740
190	77.438

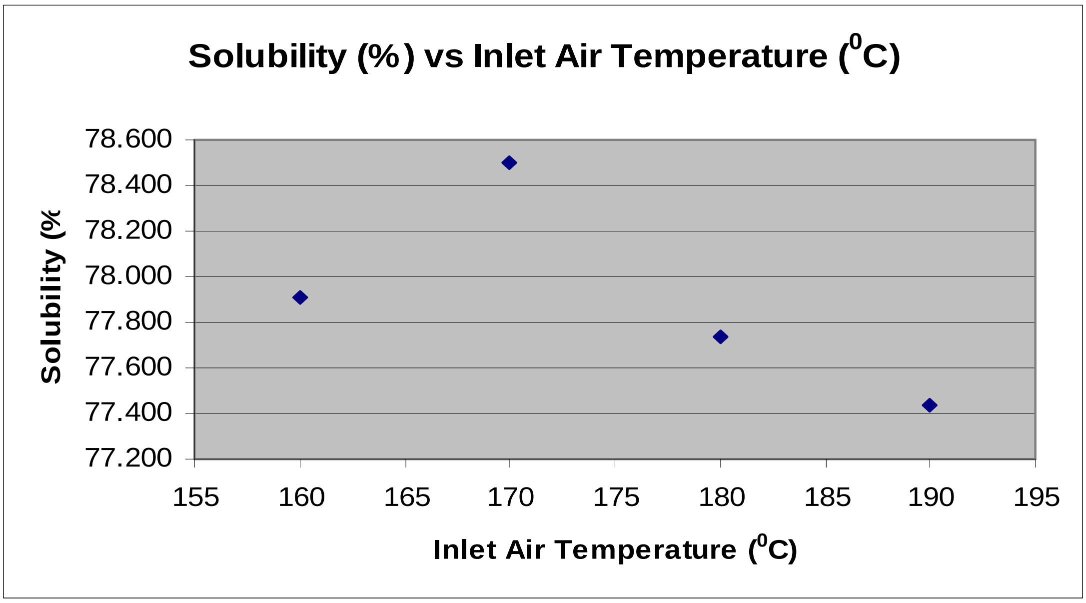

Figure 4.6: The Effect of Inlet Air Temperature on Solubility of Spray-Dried Powders.

Figure 4.6 shows solubility of powdered soursop juice in function of inlet air temperature with 10% maltodextrin addition. As stated above, that solubility problems occur when it is submitted to higher inlet air temperature. So supposedly, increasing of inlet air temperature will lead to decreasing of solubility percentage. The Figure 4.6 showed an increase in inlet air temperature will have lower solubility percent. But this fact only show when the inlet air temperature we submitted to temperature higher that 160^{0}C. This is may be due of the microstructure of soursop itself that influencing its functional solubility property. From the figure, we can conclude that the optimum value of the inlet air temperature is 170^{0}C respectively.

4.5 Powders Dissolution in Water

The dissolution test measured the reconstitution speed of spray-dried powder into water. It is expressed as time taken by the powder to fully reconstitute in water by vortexing. The dissolution is different from solubility just because of the measurement. Dissolution is measure by time taken, while for solubility it is measure by percent of solid that dissolve in water. As we can see from Table 4.7 that at lower inlet temperatures, the times taken for the powders to fully reconstitute in water were relatively shorter. This phenomenon was probably related to the moisture content of the powder produced. At lower inlet temperature, the evaporation rate was slower, producing powders with higher moisture content. This type of powders had a higher tendency of agglomeration which helped to increase the reconstitution of the powders (Abadio et al. 2004). From the results, it could be seen that there was a positive relationship between dissolution and moisture content of the powders. This is in agreement with the finding of (Goula et al. 2004).

Table 4.7: Dissolution Analysis Results of the Spray Dried Powders

Inlet Air Temperature(^{0}C)	Dissolution(s)
160	36
170	40
180	59
190	61

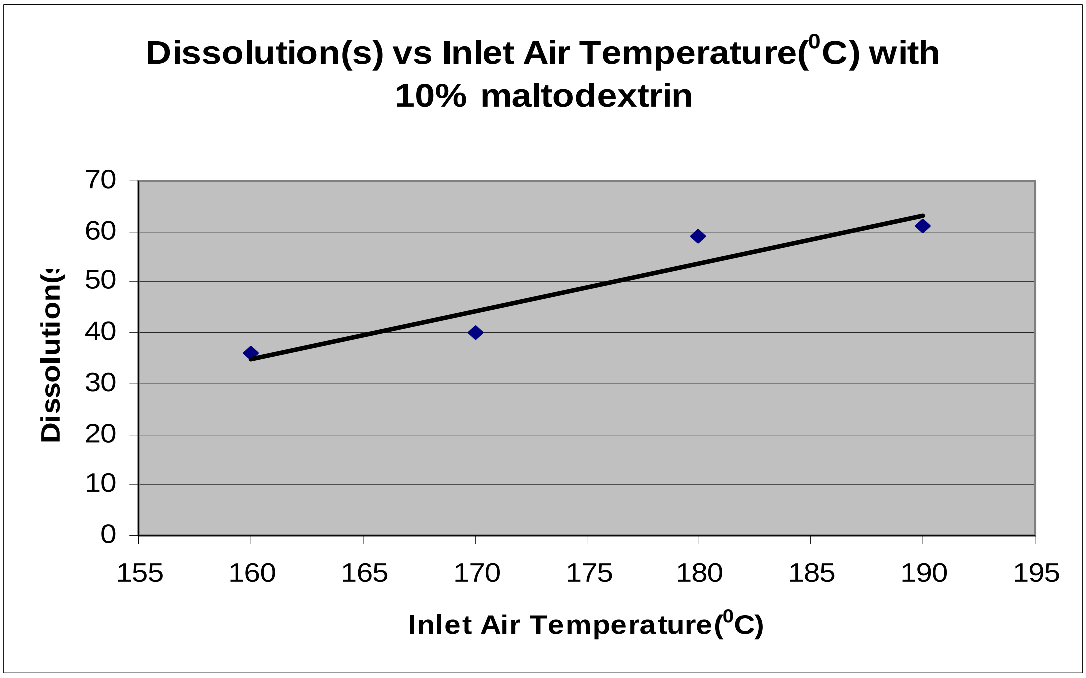

Figure 4.7: The Effect of Inlet Air Temperature on Dissolution of Spray-Dried Powders.

On the other hand, at higher inlet temperature, a hard surface layer might be formed over the powder particle. This could prevent water molecules from diffusing through the particle. So as a conclusion from the result, we take 170^{0}C as an optimum condition for inlet air temperature. Even though, 160^{0}C of inlet air temperature gives the shorter times of dissolution but still not the optimum condition because all other analysis of powders shown that 170^{0}C is the optimum condition. So there will be no doubt that 170^{0}C is the optimum condition for spray dried soursop juice.

CHAPTER 5

5.1 Conclusion

The study on the title of “Physical Properties of Soursop (Annona Muricata) Powder Produced by Spray Drying” 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 soursop powders using spray dryer and to identify the optimum condition of drying process in producing soursop powders.

The soursop juice was chosen in this research due to its important potential for the international market. The soursop 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 soursop, as scientists have been studying its properties since the 1940s. Most of the research on soursop focuses on a novel set of chemicals called Annonaceous acetogenins. Annonaceous acetogenins are powerful phytochemicals found in the Annona Muricata plant which has a long and rich history of use in herbal medicine as well as a long recorded indigenous use in the Amazon region. Its many uses in natural medicine have been validated by this scientific research.

The fruit pulp industry has become one of the world’s biggest agribusiness. Even tough 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 moisture content of the powder decreased while the time for reconstitution increased. Inlet air temperature showed significant effect on all the responses studied. Increasing temperature led to higher process yield and powder hygroscopicity, and to lower moisture content. 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 170^0C and 10% maltodextrin addition, the spray-dried powders have the best solubility, hygroscopicity and process yield results, reasonably low moisture content and dissolution. Drying the soursop juice above 180^0C has overall lead to inferior products due to nutrient loss. However, these results indicate that good quality powders can be produced by spray-drying soursop juices for potential use.

5.2 Recommendation

All the physical properties of the powders that being study in this research are very important to ensure the production of high quality soursop 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 chemical and biological properties such as sensory evaluation and microbial activity. So as the recommendation, I suggest that further investigation is needed to address the surface stickiness issue and the morpology of the soursop juice and powders itself in relation to the shelf life of the product. Addition of anti caking agent also can be considered in order to preserve the product from surrounding. Adoption of this technology could, therefore, open up a new market opportunity for the soursop 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 A

Production of Powders

Volume Juice= 300ml

Fan Setting= 15

Pump Setting= 5

Inlet Air Temperature(^{0}C)	Maltodextrin Concentration (%)	Powder Obtained(g)
160	10	3.164
	15	4.145
	20	6.097
	25	5.799
170	10	5.522
	15	6.874
	20	3.612
	25	11.671
180	10	19.806
	15	8.239
	20	9.200
	25	10.615
190	10	35.351
	15	5.549
	20	9.866
	25	11.611

Dissolution Test

Mass of Powder = 50mg

Volume of Distilled Water = 1ml

Powders Conditions		Time Reconstitute (s)			
Inlet Air Temperature(^{0}C)	Maltodextrin Concentration (%)	1st trial	2nd Trial	3rd Trial	Average Value
160	10	79	16	13	36
	15	45	32	41	39
	20	36	51	36	41
	25	48	41	33	41
170	10	49	32	38	40
	15	44	35	51	43
	20	46	40	39	42
	25	46	55	47	49
180	10	62	51	65	59
	15	43	35	57	45
	20	49	44	47	47
	25	61	54	65	60
190	10	59	61	64	61
	15	42	44	70	52
	20	59	64	56	60
	25	71	59	68	66

Moisture Content Test for Feed Mixtures

Maltodextrin Concentration (%)	Moisture Content (%)			
	1st trial	2nd Trial	3rd Trial	Average Value
10	73.052	73.076	73.197	73.108
15	69.829	70.278	69.958	70.022
20	67.379	67.201	67.546	67.375
25	64.779	64.847	64.453	64.693

Moisture Content Test for Powders Produced

Powders Conditions		Moisture Content (%)			
Inlet Air Temperature(^{0}C)	Maltodextrin Concentration (%)	1st trial	2nd Trial	3rd Trial	Average Value
160	10	0.0263	0.0313	0.0109	0.0228
	15	0.0203	0.0213	0.0219	0.0211
	20	0.0301	0.0129	0.0228	0.0219
	25	0.0762	0.4622	0.6870	0.4085
170	10	0.0305	0.0065	0.0064	0.0145
	15	0.0175	0.0134	0.0174	0.0161
	20	0.0237	0.0151	0.0581	0.0323
	25	0.0244	0.0154	0.0114	0.0171
180	10	0.232	0.2297	0.306	0.2559
	15	0.0237	0.0151	0.0581	0.0323
	20	0.2299	0.3089	0.2315	0.2568
	25	0.0000	0.0770	0.0000	0.0257
190	10	0.0767	0.0764	0.0769	0.0767
	15	0.1543	0.0000	0.0770	0.0771
	20	0.0768	0.1530	0.1541	0.1280
	25	0.2331	0.2317	0.2320	0.2323

Hygroscopicity Test

Powders Conditions		Hygroscopicity (%)
Inlet Air Temperature(^{0}C)	Maltodextrin Concentration (%)	Average Value
160	10	12.775
	15	13.745
	20	14.172
	25	13.373
170	10	8.532
	15	9.800
	20	15.968
	25	16.932
180	10	9.452
	15	11.501
	20	14.911
	25	13.147
190	10	14.763
	15	15.168
	20	14.881
	25	19.200

Solubility Test

Powders Conditions		Solubility (%)			
Inlet Air Temperature(^{0}C)	Maltodextrin Concentration (%)	1st trial	2nd Trial	3rd Trial	Average Value
160	10	77.915	77.910	77.906	77.910
	15	76.574	76.577	76.596	76.583
	20	79.082	77.423	81.918	79.474
	25	76.900	78.322	77.246	77.490
170	10	77.656	78.222	79.620	78.499
	15	75.387	75.412	75.247	75.349
	20	74.810	77.667	76.969	76.482
	25	79.195	77.932	83.100	80.076
180	10	78.781	77.516	76.924	77.740
	15	77.349	77.396	77.233	77.326
	20	77.176	77.600	77.092	77.289
	25	77.164	77.246	76.969	77.126
190	10	77.734	77.458	77.121	77.438
	15	76.900	76.823	77.922	77.220
	20	76.796	76.700	76.892	76.796
	25	76.900	76.946	77.423	77.090

Total Solid Content of Feed Mixtures

Maltodextrin Concentration (%)	Total Solid Content (%)
10	26.892
15	29.978
20	32.625
25	35.307

Total Solid Content of Powders Produced

Powders Conditions		
Inlet Air Temperature(^{0}C)	Maltodextrin Concentration (%)	Total Solid Content (%)
160	10	99.977
	15	99.979
	20	99.978
	25	99.592
170	10	99.986
	15	99.984
	20	99.980
	25	99.983
180	10	99.744
	15	99.968
	20	99.743
	25	99.974
190	10	99.923
	15	99.923
	20	99.872
	25	99.768

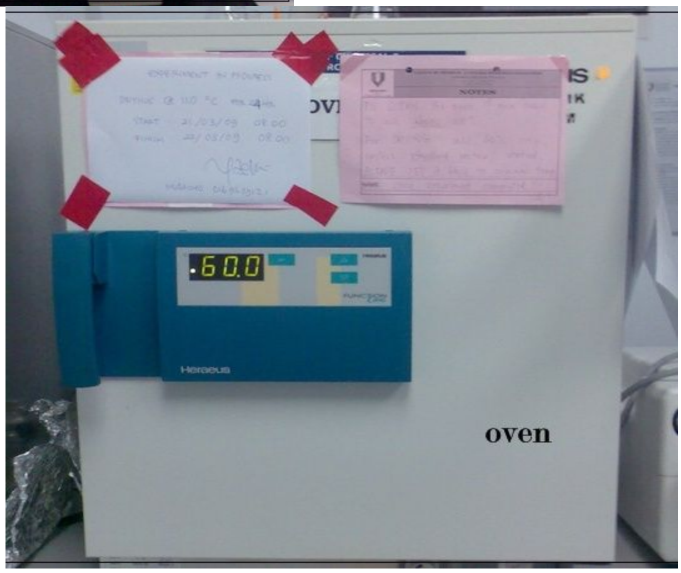
Process Yield

Process yield = total solids content in powder- total solids content in feed mixtures

Inlet Air Temperature(^{0}C)	Maltodextrin Concentration (%)	Process Yield (%)
160	10	71.285
	15	70.001
	20	67.353
	25	64.285
170	10	71.294
	15	70.006
	20	67.355
	25	64.676
180	10	71.052
	15	69.990
	20	67.118
	25	64.667
190	10	71.231
	15	69.945
	20	67.247
	25	35.307

APPENDIX B


refrigerated
centrifuge
eppendorf
Centrifuge 5810 R
REFRIGERATED
CENTRIFUGE


60.0
Heraeus
oven


vacuum oven
FISHER


HOT PLATE & MAGNETIC STIRRER
hot plate stirrer


maltodextrin grade 10


weighing boat


Suction of
Cyclone
Product Vessel
20-Jan-09 11:10 am
LabPlant
System Ready
SD 06 PUMP
<< Stop Stop >>
STOP
START
NEXT
PUMP
ESC
ENTER
Control