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**RESEARCH MANAGEMENT CENTRE**

# EFFECT OF VARIOUS PROCESSING PARAMETERS ON THE QUALITY OF PAPAYA FRUIT TEA


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# CHAPTER I

# INTRODUCTION

## 1.1 Research background

Exotic fruits from which drinks are made in most tropical countries are so abundant and such in a great variety, that it would probably be impossible for people to sample all of them, but they worth a try. Some of the great varieties of fruits used in drinks are bananas, guavas, papayas, oranges, pineapples, grapes, mangoes, watermelon, coconuts, longans, rambutans, strawberries, lime and tamarind.

From the various fruits listed, papaya is found to be one of the easiest fruits grown in all tropical countries. It is grown extensively in all tropical and sub-tropical parts of the world. Papaya is a wholesome, all season fruit. It has more carotene compared to other fruits such as apples and guavas, which is converted into vitamin A in our body. It also contains vitamins B, D, E, K and C, and minerals such as sodium, magnesium, iron, calcium, phosphorus and potassium. Rich in vitamin A and C, papaya has been used to heal ulcers and other internal bleeding.

For nowadays, papaya fruits have been commercialized in various ways of marketing ranging from drinks to food and even more vitamins supplement. There are pure papaya fruit juice, concentrated fresh juice, bottled soft drinks, fruits shake with crushed ice and milk or cream, papaya fruit powder drink and papaya flavored tea drink. More and more people have shown their attraction towards papaya in their daily meals. As for that, a new way of commercializing papaya fruit drink is proposed to meet the needs of consumer health and pleasure.

Papaya fruit drink is expected to be a nutritious beverage by maintaining the quality of the processed papaya fruit. The quality is indicated by the ability to retain the original coloring, taste, aroma and its biological active gradient throughout the process. Drying method and various processing parameters has huge effects on the quality of dried fruits. It is reported that drying method will seriously decrease the nutritive and sensorial values cause by water removal of the fruits (Lenart, 1996). The degradation rate of quality increases as the drying temperature increases. Hence, selection of proper drying technique and conditions is necessary for minimizing thermal stresses, over drying and maintenance of relevant compounds in order to retain the quality of the dehydrated product.

## 1.2 Objective of study

The objective of this research is to study the effects of processing parameters during various dehydration processes on the quality of dehydrated papaya.

## 1.3 Scope of study

The scopes of this research include:

- Tray drying, osmotic dehydration and microwave drying process.
- Analysis on moisture content and drying characteristics of dehydrated papaya.
- Analysis and ddetermination of papain enzyme activity of dehydrated papaya.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Papaya fruit

### 2.1.1 Origin

Papaya with the scientific name, *Carica papaya* is a common fruit to be found in tropical countries. It is a succulent fruit of the family Caricaceas. Papayas are usually grown from seed. Their development is rapid, fruit being produced before the end of the first year. Under favorable conditions, a papaya plant may live for five years or more.

Papaya is oval in shape and the colour of the skin is green if unripe. It will turn to green yellowish when it is ripe. The flesh of papaya is white before maturity, turns to a rich orange-yellow or deep rose when ripe, with colour varying according to variety. Papaya fruit is sweet in taste, with an agreeable musky tang, which is more pronounced in some varieties and in some climates than in others.

### 2.1.2 Content of papaya

Papaya has been regarded as one of the most valuable tropical fruits that contains many biological active compounds. Different types of enzymes are present in papaya. Protease enzyme, also known as papain is a protein-digesting enzyme. This substance presents in papaya is an excellent aid to digestion. This enzyme greatly resembles the animal enzyme protein in its digestive action. It has a high commercial value because of its ability to hydrolyze protein. Papain also exhibits pain relieving properties and the United States Food and Drug Administration has approved its medicinal use to ease the discomfort of slipped discs. This is used for injection into herniated inter vertebral lumbar discs to relieve pain caused by the pressure on nerves.

Papaya when consumed regularly will ensure a good supply of vitamin A and C. It also contains vitamins B, D, E, K and C, and minerals such as magnesium, sodium, iron, calcium, phosphorus and potassium. Rich in vitamin A and C, papaya has been used to heal ulcers and other internal bleeding. Healing speeds up with pieces of papaya laid on wounds and surgical incision.

Papaya is a good source of beta-carotene, which helps to prevent damage by free radical, which may other wise lead to some forms of cancer. It has more carotene compared to other fruits such as apples and guavas. Carotene in food is converted into vitamin A in people's body. Papaya is a low calorie fruit compared to others. 100 grams of ripe papaya contains only 32 kcal. The comparative low calories content make this a favorite fruit of obese people who are into weight reducing regime. This low calorie, nutritive and low in cost fruit is the best dietary supplement for a healthy life. It will be more convenient if papaya fruit is processed as drinks that can be included in our regular daily meals. The characteristics of papaya such as the aroma, flavor, color, nutrient content and enzymatic concentration are expected to be retained for a high quality dehydrated papaya throughout this research.

| **Components** | **Every 100g** |
|---|---|
| Energy | 35.0 cal |
| Moisture | 90.7 g |
| Protein | 1.5 g |
| Fat | 0.1 g |
| Carbohydrates | 7.1 g |
| Fiber | 0.5 g |
| Ash | 0.1 g |
| Calcium | 11.0 mg |
| Phosphorus | 3.0 mg |
| Iron | 0.7 mg |
| Sodium | 3.0 mg |
| Potassium | 16.0 mg |
| Beta carotene | 1160.0 µg |
| Vitamin B1 | 0.03 mg |
| Vitamin B2 | 0.07 mg |
| Niacin | 0.1 mg |
| Vitamin C | 71.0 mg |

**Table 1.** Components in papaya fruit
*(Source: Malaysian Food Nutrition Composition, IMR 1982)*

## 2.2 Drying process

### 2.2.1 Definition of drying

Drying is a process in which water is removed to halt or slow down the growth of spoilage microorganisms, as well as the occurrence of chemical reactions (Vega-Mercado *et al.,* 2001). Drying is usually defined as the removal of moisture until equilibrium with the environment, while the removal of moisture to a very low moisture content, nearly bone-dry condition is called dehydration (Stuchly *et al.*, 1983). The drying process can be further divided into two periods, which are the constant drying rate period and the falling drying rate period.

During the first stage of drying, the wet materials contains so much water that all existing liquid surfaces will dry in a manner comparable to an open surface of water. The drying rate depends only on the ambient conditions and the total water surface area. The drying rate is constant because the surface of the material contains free moisture. Towards the end of the constant drying rate period, moisture has to be transported from the inside of the material to the surface. The moisture content at which the drying rate ceases to be constant is called the critical moisture content.

After the constant drying rate period, dry spots appear on the surface and the drying rate decreases. This is called the falling rate period, in which two processes involved: the movement or migration of moisture within the material (mass transfer) to the surface and the removal of moisture from the surface. When the surface is completely dry, the moisture is transported from the inner parts of the material to the external surface as the result of concentration gradients between the interior of the material and the surface (Mujumdar, 1995).

### 2.2.2 Drying technology

Drying of food has been widely used for preservation of food in the last few years. There are as many reasons as there are materials that can be dried. Dried food, especially fruits and vegetables can be stored and transported at a relatively low cost. The handling of product marketing will be easier and faster. However, water removal during drying leads to a serious decrease in the nutritive and sensorial values of the product (Lenart *et al.,* 1996). Several factors should be considered in order to apply drying for food preservation to achieve the best possible quality of the product. Akanbi *et al.* (2005) studied on drying characteristics of tomato slices, including moisture content at different drying temperature. A research has to be undertaken in order to obtain the most optimum drying method and processes for higher product quality of nutrient, enzymatic reaction and sensory acceptability retention.

Drying technology has evolved from the simple use of solar energy to current technology that includes, among others, kiln drying, tray drying, tunnel drying, spray drying, freeze dehydration, osmotic dehydration, extrusion, fluidization, and the use of microwaves, radio frequency, refractance window and hurdle technology. The development of dehydration technology can be divided in four groups or generations (Vega-Mercado, 2001) as shown in Fig. 1.

| | First Generation | Second Generation | Third Generation | Forth Generation |
|---|---|---|---|---|
| Type of Dryer | Cabinet and bed type dryer such as kiln, tray, truck tray, rotary flow conveyor and tunnel | Spray dryer and drum dryer | Freeze dehydration and osmotic dehydration | High vacuum, fluidization, microwaves, radio frequency and refractance window |
| Mechanism | Hot air flows over an extensive area of the material to remove water from the surface | Atomization of the feed into a drying medium, resulting in moisture evaporation | Immersion of material in a hypertonic solution such as sugar or salt or glycerol | Specific application, based on the final quality attributes of the intended products, and physical and chemical characteristics of raw materials being processed |
| Materials | Solid materials such as grains, sliced fruits and vegetables or chunked products | Slurries and purees End products are dehydrated powders and flakes | Fruits and vegetables | Various food processing materials |
| Advantages | Common drying process | Involve both particle formation and water removal, Intended for production of powders and flakes | Overcome structural damages and minimize losses of flavor and aroma compounds | Latest advance in drying process, Has specific application, Energy saving, Reduction in processing time |

Fig. 1. Generations of the development of dehydration technology

## 2.3 Microwave drying

Microwaves heating and drying processes have been well established in various industrial applications, and in many cases are replacing the less efficient, less economic and less convenient conventional methods of drying. In recent years, microwave drying has gained popularity as an alternative drying method in the food industry. Microwave drying is rapid, more uniform and energy efficient compared to conventional hot- air drying. Microwaves are of increased interest among food researchers and processors because of its energy saving possibilities they might represent. However, microwave drying should be fully understood in order to avoid lack of optimization, particularly with regard to uniformity of moisture and temperature distributions in the treated material. The microwave oven equipment is shown in Fig. 2.

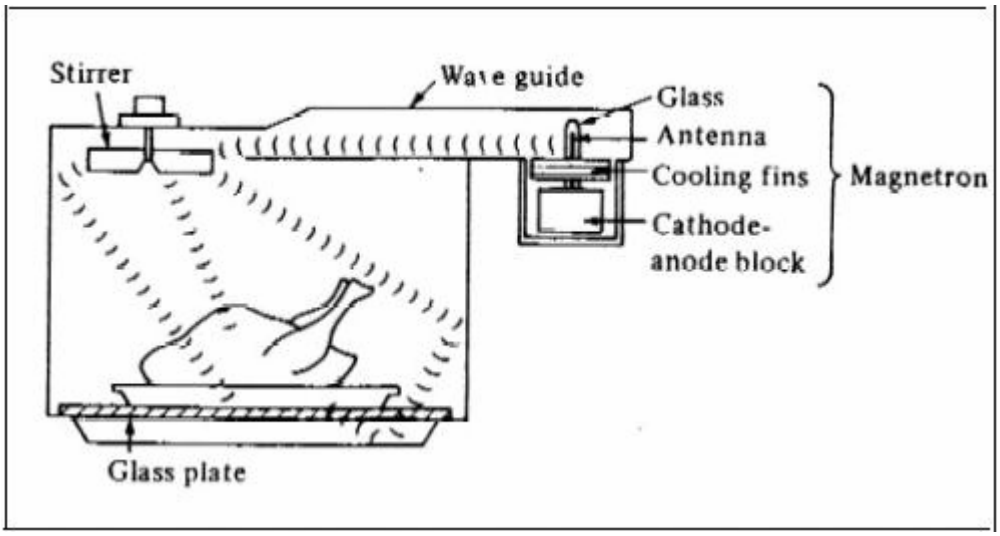



**Fig. 2.** Microwave oven drying unit

Numerous electromagnetic and thermal parameters are involved in the microwave heating and drying process. The apparent limitations of the microwave process are established by the material quality, processing time, temperature and moisture distributions (Stuchly *et al.*, 1983). In other words, the process rate depends on the maximum permissible temperature and moisture gradients. It is therefore obvious that the product quality is improved by the reduction of moisture and temperature gradients.

Microwave drying of foodstuffs gives rise to complicated chemical conversions and reactions. Such reactions can cause degradation of vitamins, lipid oxidation and browning reactions. However, the retention of vitamins during blanching, cooking and reheating of foods in a microwave oven was found to be comparable to the retention using conventional methods of heating. In the conventional drying process, moisture is removed initially from the external surface of the body producing the internal moisture gradient necessary for outward diffusional moisture flow. As a result of the relatively dry surface, case-hardening, shrinkage, local overheating and structural damage of materials are very common. In this case, microwave process has the potential to be the latest advance in drying technology to overcome such problems contributed by the conventional drying process.

It was observed that temperature in the interior of dried food in microwave procedure is higher than on the surface and moisture is trabsferred to surface more dinamically than during conventional drying method. The simulation results showed that in larger samples, heating occurs mainly from the surface towards the centre, whereas in smaller samples, heating is also significant at the inner parts of the sample (Oliveira *et al.*, 2002). Rotation of the samples in microwave drying caused a decrease in temperature gradients, resulting in more uniform temperature distributions.

A microwave-generated thermal gradient produces a completely different moisture distribution in the dried body. Because of the exponential dependence of the diffusivity on temperature, the diffusional flow rate for a given moisture gradient will be much higher near the centre of the bulk than near the surface (Stuchly *et al.*, 1983). As a result, a strong moisture-leveling process exists as moisture gradients decrease with increasing depth, to compensate for the rapidly increasing diffusivity. Moisture content will decrease more uniformly throughout the bulk and thus eliminate part of the disadvantages of the conventional drying process. Fig. 3 shows the schematic representation of microwave drying unit.

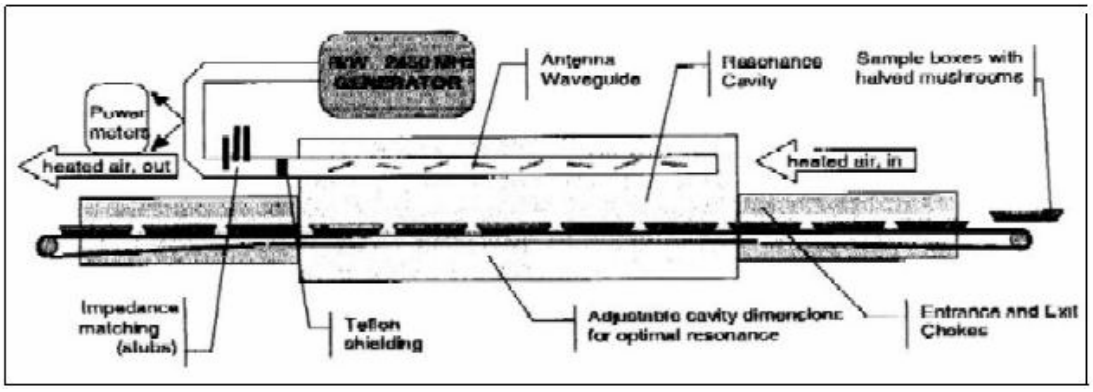



**Fig. 3.** Schematic representation of microwave drying unit

## 2.4 Microwave-assisted air dehydration

The progresses in microwave drying on the industrial level has been relatively slow in comparison with the laboratory level because of its high initial capital investment and comparatively lower energy efficiency with conventional drying techniques (Piotrowski *et al.*, 2004). Removing water by means of microwaves is expensive because of high costs of electric energy. For lowering costs, usually a combination of microwave drying with conventional drying is taken into account. The schematic illustration of microwave-assisted air dehydration equipment is shown in Fig. 5.

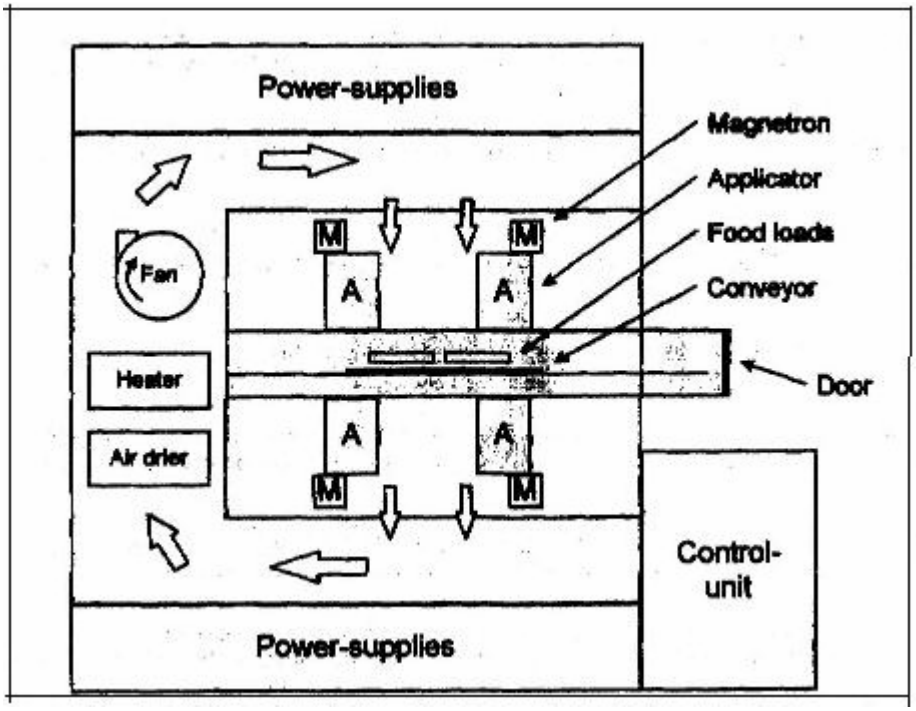



**Fig. 5.** Schematic illustration of microwave-assisted air dehydration equipment

### 2.4.1 Conventional drying

A tray or compartment dryer is an enclosed, insulated housing in which solids are placed upon tiers of trays in the case of particulate solids. Heat transfer may be direct from air to solids by circulation of large volume of hot air. A conventional

drying unit is shown in Fig. 6. A conventional tray dryer consists of removable tray loaded in a cabinet in which loading of fruit cubes is provided. It essentially consists of an insulated cabinet containing an air circulating fan that moves the air directly through a heater and adjustable baffles. The air moves either horizontally between the trays of food material or vertically through the trays and food.

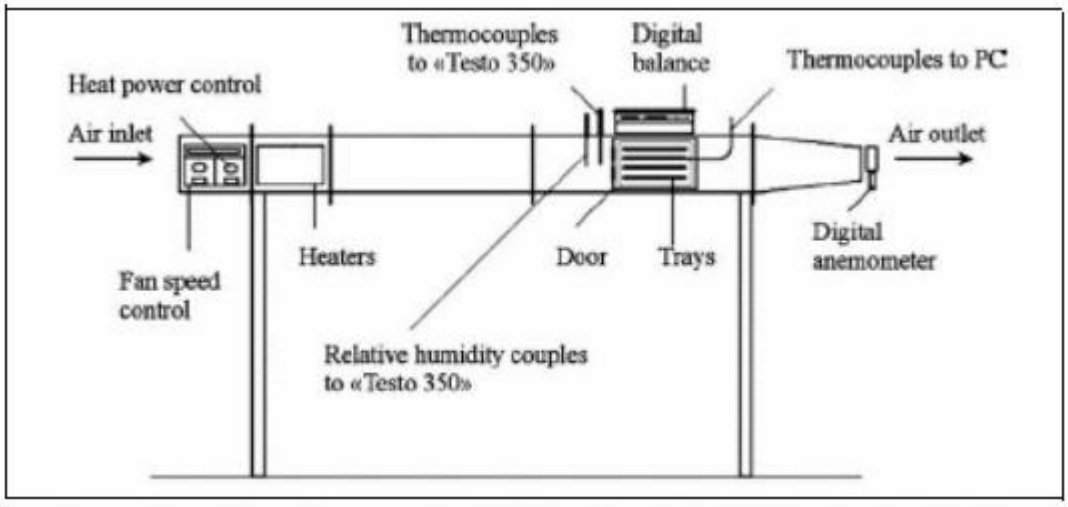



**Fig. 6.** Schematic diagram of the convection drying equipment

The major concern in hot air drying of fruits is the tremendous energy consumption and low drying efficiency (Yongsawatdigul *et al.*, 1996). The conventional hot air method of drying fruits often degrades product quality. Van Arsdel *et al.* (1973) indicated that hot air drying can cause heat damage and adversely affect flavor, color, size, texture, nutritional value and enzymatic reaction of the products. Case-hardening is a common defect particularly found in dried fruits due to rapid drying. As drying progresses, the rate of water evaporation is faster than the rate of diffusion to the product surface (Yongsawatdigul *et al.*, 1996). Therefore, the outer skin becomes dry and acts as water barrier, causing a wet interior. Furthermore, loss of volatile compounds inevitably occurs during this conventional drying. Since the fruits material are exposed to high temperature for a long period, these volatile compounds are vaporised and lost with water vapor. This causes a significant loss of characteristic flavor and aroma in dried products. High temperature and long drying time also diminished the original color of the products.

#### 2.4.1.1 Parameters: temperature, air velocity and geometry of fruit

The quality of dried fruit is highly depended on the optimum drying conditions. To achieve the best possible quality, selection of proper drying conditions is necessary for minimizing thermal stresses and maintaining the relevant compounds, which determine the quality of the product (Ramesh *et al.*, 2000).

In tray drying process, temperature of air significantly plays an important role to dehydrate the fruits to an acceptable moisture content. High temperature of hot air may result in faster moisture or water removal of fruit and better effectiveness of diffusivities. However, an excessive air temperature will reduce the sensorial and quality of the fruit and may cause seriously damage in flavors, colors and nutrients. Lower temperature of hot air is not expected to alter the properties of the fruit significantly but more time is required to reduce the moisture content to an acceptable amount.

Air velocity that moves through the fruit loaded on the tray is also aiding the heat and mass transfer of the drying process. The water was transferred through the air and was carried away. When air velocity increased, the effective water diffusivity also increased.

It is very common in literature to consider finite food geometry as an infinite flat plate configuration, neglecting the diffusion in the other direction. In other word, geometry of cutting size usually does not take into consideration. However, it is important to take into account the effect of geometry of fruit cut for the purpose of comparison among various drying methods.

Geometry or shape of cutting size influences the peripheral of diffusion of fruit during drying process. Breadth flat surface tends to increase the drying rate rather than denting surface that obstruct water diffusion from the fruit into the air

during drying process. Other consideration is the thickness of cutting size. Rastogi *et al.* (2004) reported that when thickness is very small as compared to length and breadth of fruit cut, the peripheral diffusion is negligible. However, when thickness is of equal magnitude to length and breadth, which indicates that the fruit was cut into cubes, this assumption is no longer valid because more consideration was required to account for the peripheral diffusion, considering the food piece as a rectangular rather than an infinite plate.

### 2.4.2 Osmotic dehydration

Osmotic dehydration is a useful technique that involves product immersion in a hypertonic aqueous solution leading to a loss of water through the cell membranes of the product and subsequent flow along the inter-cellular space before diffusivity in the solution (Sereno *et al.*, 2001). It is an efficient form of moisture removal from solid food, causing no change of phase of the water.

Osmotic dehydration is mainly intended for processing fruits and vegetables. Osmotic dehydration is a method used for attaining better quality fruits and is used as a preliminary drying period. This method is based on the immersion of fruits in a hypertonic solution of sugar. This hypertonic solution presents a higher osmotic pressure and a lower water activity. In the osmotic process, this semi-permeable membrane is represented by the cellular surface structure of the fruits.

Osmotic dehydration can be used as a pre-treatment for drying process of fruits. This technique also allows the incorporation of certain solutes, without modifying the integrity of the product. The product will become tastier and last longer. Osmotic dehydration is said to be one of the way for food preservation. The water removal from solid foods inhibits the growths of microorganisms, besides

preventing a large part of biochemical reactions which occur in the presence of moisture. The process of osmotic dehydration promotes stabilization of color parameters, reducing non-enzymatic browning reactions and often improves fruit product color (Krokida *et al.*, 2000). Furthermore, the dehydration is also a mean of reducing energy costs, important for the transportation, packaging and storing of foods with high water content (Park *et al.*, 2002).

#### 2.4.2.1 Influence of process variables on osmotic dehydration

a) Temperature

Temperature of dipping pretreatment of osmotic dehydration has huge influences on the drying time, drying kinetics and the organoleptic properties of the osmo-dehydrated products. Pangavhane *et al.* (1999) studied the effect of different pretreatment parameters on the quality of seedless grapes. It was reported that with cold dipping pretreatment, the drying time of the grapes reduced significantly with better quality raisins produced compared to those obtained from untreated grapes. While for hot dipping pretreatment, though the drying time was further reduced, the quality of raisins produced was found to be poor. Moreover, the hot dipping method was also not convenient to handle.

b) Geometry of fruit cut

The most common geometries used in drying of fruits are cubes and slices. El-Aouar *et al.* (2003) used $2cm^3$ cubes of papaya in their study, while Araujo *et al.*(2004) cut the sample of nectarine (*Prunus persica*) into flat slabs in their study.

Graziella *et al.*(2004) studied the geometry of papaya fruit cut as one of the independent variables for osmotic dehydration process to determine the water loss,

weight loss and solid gain of dehydrated papaya. They reported that papaya slices provided more water loss, weight loss and solid gain compared to cubes.

c) Sucrose and lactic acid concentration

Sucrose concentration has influences on the solid gain and water loss of the dehydrated fruit. Sucrose exhibits fast diffusion inside cells. Previous studies showed that sucrose concentration used was usually ranging from 50°Brix to 70°Brix. Silveira *et al.*(1996) reported that water loss and solid gain increased with increasing sucrose concentration. While Giraldo *et al.* (2002) reported that effective diffusion coefficient in the mango fruit liquid phase increased when sucrose concentration decreased.

## 2.5 Quality of dehydrated papaya

### 2.5.1 Vitamin C content

Papaya (*Carica papaya L.*) is one of the major sources of vitamin C. It was reported that papayas contains 16% more vitamin C than oranges. Vitamin C is an important anti-oxidant compound that helps protect against cancers, heart disease and stress. Vitamin C helps in maintaining healthy immune system since it is needed for antibody production besides increasing the absorption of nutrients in the gut.

#### 2.5.1 1 Factors of vitamin C degradation

Degradation of ascorbic acid depends on several factors as below:

a) Drying condition

Vitamin C is a heat sensitive compound compared to other nutrients and this may cause problems to retain it whenever exposed to heat. Raising the drying temperature increases the loss of vitamin C.

b) Oxygen

Presence of oxygen may cause loss of vitamin C since it is a type of anti-oxidant compound. Oxidation of food ingredient such as acid ascorbic or other vitamins, pigments and aroma compounds is one of the most important causes of quality loss. Accordingly, the absence of air during drying may inhibit oxidation and

therefore, nutrient content such as acid ascorbic, color and aroma compound of product can be largely preserved. Processing under low oxygen conditions in an inert atmosphere and control drying conditions of temperature, air velocity and relative humidity may lower the oxidative effects and maintain the nutritional value of the process food.

c) Cutting size of fruit

In some cases of fruit drying, it is significant to have shorter drying time. To achieve shorter drying time, most of the fruits were chopped before drying. However, chopped fruit may cause loss of nutrients such as vitamin C. Hence, cutting size might also influence vitamin C retention. Larger surface area exposed to heat may increase the degradation of vitamin C.

d) Sample moisture content

The stability and retention of vitamin C depended on the sample moisture content, due to its solubility in the water. According to previous study on rosehip, high rate of vitamin C loss was found at a relatively higher moisture content at the beginning of drying, followed by a period of less rapid degradation as the moisture content decreased. The high rate of loss at the beginning of the drying process may be attributed to high moisture content of the material. This proves that the stability and retention of vitamin C is not only depended on drying conditions but also on sample moisture content.

### 2.5.2 Papain enzyme

Enzymes are biological catalysts that have the ability to increase the rate of chemical reaction and will not be destroyed by the chemical reaction that is accelerates. Protease refers to a group of enzyme that has a very beneficial function through its ability to hydrolyze almost all proteins. They are also known as proteolytic enzymes that are very important in digestion as they catalyses the breakdown of peptide bonds in protein foods to liberate the amino acids needed by the body. Additionally, protease enzymes have been used for many applications and various forms of therapy, which are mostly used in medicine based on several clinical studies indicating their benefits in inflammatory conditions and blood rheology control. Besides, they have the ability to digest the unwanted debris in the blood including certain bacteria and viruses.

Papain is a sulfhydryl protease from *Carica papaya* latex. Papain degrades most protein substrates more extensively than the pancreatic proteases. Papain is a single peptide chain of 211 residues folded into two parts that form a cleft. Papain is activated by cysteine, sulfide and sulfite. It is enhanced when heavy metal binding agents such as EDTA are also present.

Papain is used in the pharmaceutical industry, in medicine as well as in the food processing industry. It is used in the preparation of vaccines and for the treatment of hard skin. It also has veterinary applications such as deworming of cattle. If papain is to be exploited commercially for an export market or local food industry use, it is important to be able to determine the enzyme activity.

### 2.5.2.1 Factors of papain stability

a) Temperature

Temperature is the major effect of enzyme stability. Enzymes are very sensitive to heat since they are biochemical catalysts that made up at least partially protein. This will cause problem to retain papain enzyme during drying since temperature is the main parameter in the process. Furthermore, raising temperatures of the environment generally multiplies the degree of enzyme, but once an optimum temperature has been reached, rapid degradation of the enzyme will occur with concurrent and irreversible loss in activity. However, the optimum temperature generally ranges from 37 ˚C to 60 ˚C.

b) pH of the environment

The pH of the environment affects the enzyme activity and stability. Optimum pH for enzyme activity varies for most enzymes including proteases. However, the optimum pH for the biological catalyst lies between pH 4.5 to 7.5.

# CHAPTER III

# METHODOLOGY

## 3.1 Raw material

Mature green papaya has been selected for the purpose of producing papaya fruit drinks as it contains high papain enzyme and vitamin C. The Brix index of the selected papaya should be within 10 - 12°Brix. The Hawaiian type of papayas were supplied by MARDI, Pontian. The fruits were hand-peeled and cut into slices (4.0 x 2.0 x 0.5 cm) and cubes (2.0 x 2.0 x 1.0 cm).

## 3.2 Drying procedure

### 3.2.1 Microwave drying

Drying processes were carried out using microwave oven (Sharp R-4A53) with various processing parameters. Drying procedure followed Wang *et al.*(2005) with slight modification. Different geometry (slices and cubes) of papaya were treated in microwave oven at different levels of power intensities (110 W, 380 W, 750 W) until the sample weight became constant. Sample weight was determined by the digital balance weight. The weight was taken every 10 seconds to determine the moisture content of the samples.

### 3.2.2 Microwave-assisted air dehydration

Microwave drying processes were carried out using microwave oven. Different geometry (slices and cubes) of papaya were treated in microwave oven at different levels of power input (110 W, 380 W, 750 W) for a specified time before treated in an oven at different temperature (20, 40 and 60°C). Maximum drying temperature was selected at 60ºC because degradation of enzyme occurred at temperature higher than 60ºC.

### 3.2.3 Tray drying

The tray drying procedure followed Park *et al.* (2002) with slight modification. Drying processes were carried out using tray dryer (Armfield UOP8) at different temperature (20, 40 and 60°C). Maximum drying temperature was selected at 60ºC because degradation of enzyme occurred at temperature higher than 60ºC.

The tray dryer consists of horizontal air flow through trays and samples loaded on it. Prior to this, the weight of empty tray was measured so that the weight of samples could be determined. Firstly, the air flow needs to be set up first. Air flow was adjusted by anemometer at the end corner of tray dryer where the air was supplied by the circulating fan. The drying temperature was automatically applied in the process by the electrical heater, placed at the inlet of the tray drier. Thermocouple was used in order to determine the temperature. The drying process started until it reaches steady state. Sample weight was determined by the digital balance weight. The weight was taken with time interval range of 15 – 120 minutes until the weight became constant.

## 3.3 Quality analysis of dehydrated papaya

### 3.3.1 Determination of moisture content

The moisture content was expressed on a dry basis as kg of water per kg of free-moisture solid or kg $H_2O$/kg dry solid. It was determined by an oven method, slightly modified from Funebo *et al.* (2000). Papaya slices were placed in oven (Memmert) at 100°C for 24 hours to obtain the dry weight. Time-dependent moisture content of the samples were calculated as follows:

$$MoistureContent = \frac{Wetweight - dryweight}{dryweight}$$

### 3.3.2 Enzyme analysis

#### 3.3.2.1 Extraction of papain enzyme

Prior to the extraction process, the dried sample was blended to provide more surfaces for the reaction to occur. Enzyme extraction from the dried papaya was carried out using acetone solution at ratio 5 g of sample : 10 mL of acetone. The sample bottles then need to be properly wrapped with aluminum foiled to avoid oxidation for 24 hours.

### 3.3.2.2 Determination of papain enzyme activity

A volume of 5 ml of casein substrate was pipetted into test tubes and soaked in water bath at 40°C for 15 minutes. Then 2 ml of extracted enzyme solution was added into the test tubes, followed by 3 ml of trichloroacetic acid to precipitate the protein. After 60 minutes soaked in water bath at 40°C, the sample was centrifuged and the supernatant was then measured with spectrophotometer at wavelength 280nm.

The determination was based on hydrolysis of the casein substrate. One enzyme unit (U) is defined as an enzyme activity that release 1 g tyrosine at 40°C for 60 minutes. Standard curve was prepared by plotting the absorption versus the enzyme concentration. The enzyme activity of the samples were calculated as follows:

$$U/mg = (A \times C \times 10)/ W$$

whereas; U = enzyme unit defined as an enzyme activity that releases 1g tyrosine at 40 ˚C for 60 minutes, A = standard activity of enzyme, C = concentration of enzyme, W = sample weight in mg and constant 10 represents the final mixture volume**.**

# CHAPTER IV

# FINDINGS AND DISCUSSION

## 4.1 Processing effects

### 4.1.1 Microwave drying

The effect of microwave drying parameters and geometry of papaya fruit cut on the dehydrated product is studied The moisture content versus time curves during microwave drying of papaya cubes for each of power intensities studied are shown in Fig. 1, 2 and 3. As the microwave power intensity increased, the time required to achieve moisture content to nearly zero decreased. The processing time for microwave power 380 W and 750 W were slightly the same. However for microwave power 110 W, the time required to remove the moisture until low moisture content in papaya cubes is 20 minutes, compared to 4 minutes for 380 W and 750 W.

The effect of changing the microwave power intensity on the drying characteristics of papaya cubes is shown in Fig. 4. Drying rates were higher during higher moisture content and decreased with decreasing moisture content. The drying rate increased with increasing of power intensity at the same moisture content. The comparison made for power intensity showed that at lower microwave power, the drying rate was low and increased during higher power levels. The results indicated that mass transfer is rapid during larger microwave power heating because more heat was generated within the samples, creating a larger vapor pressure differential between the centre and the surface of products (Lin et al., 1998). Although papayas have high moisture content, an expected constant rate period was not observed in this study. It is obvious that the entire drying process for the samples occurred in the range of falling rate period.

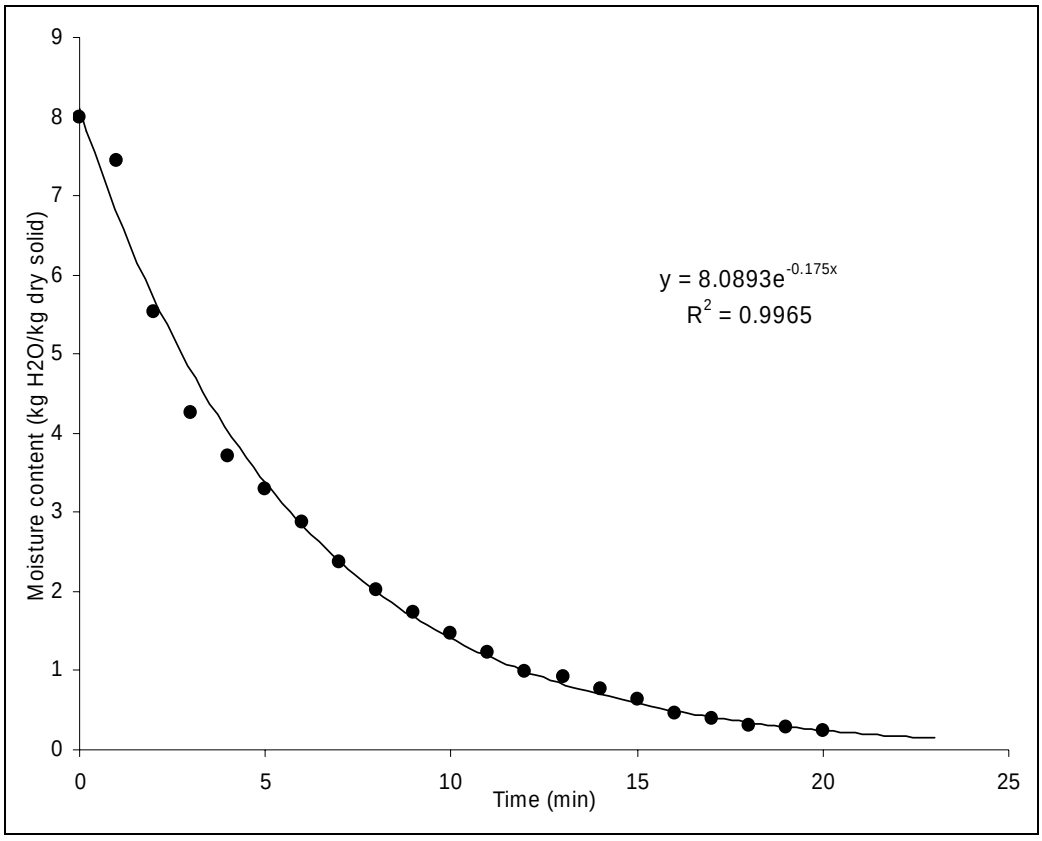



Fig. 1. Moisture content curve for microwave power 110W

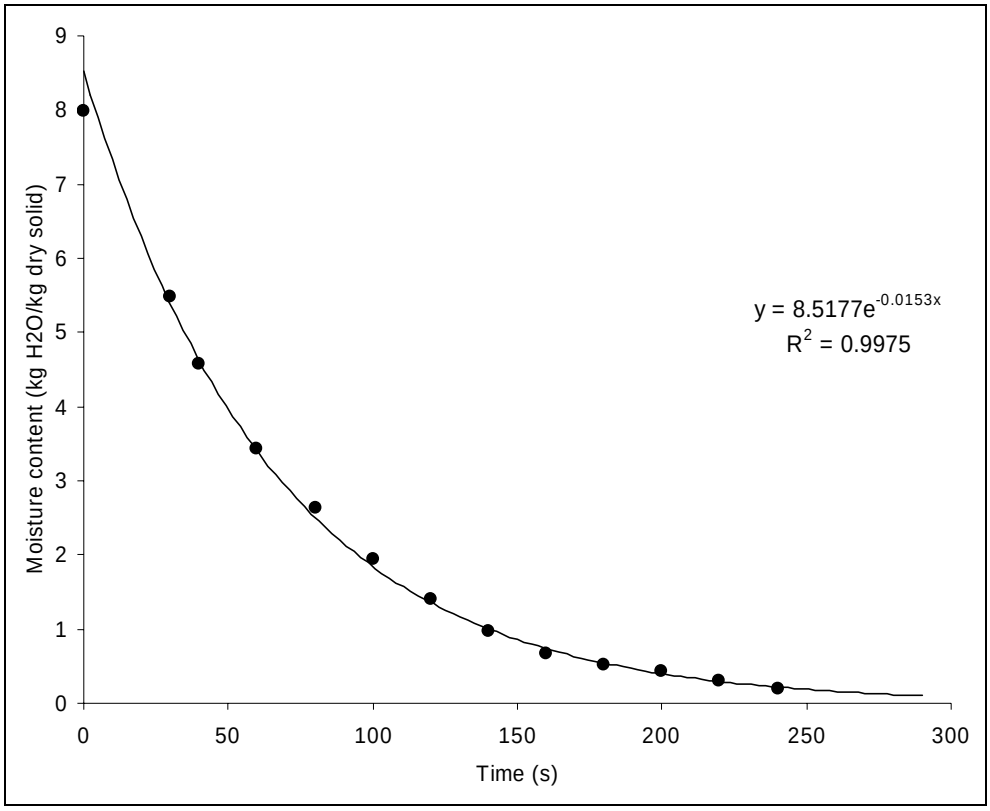



Fig. 2. Moisture content curve for microwave power 380W

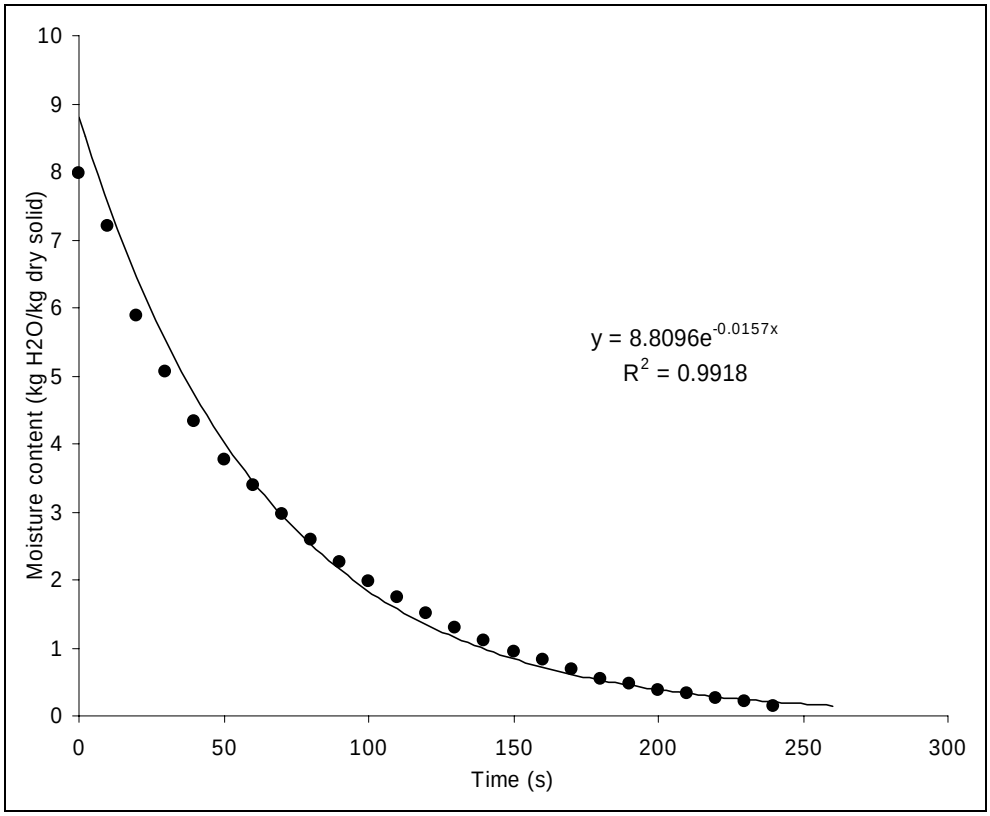



Fig. 3. Moisture content curve for microwave power 750W

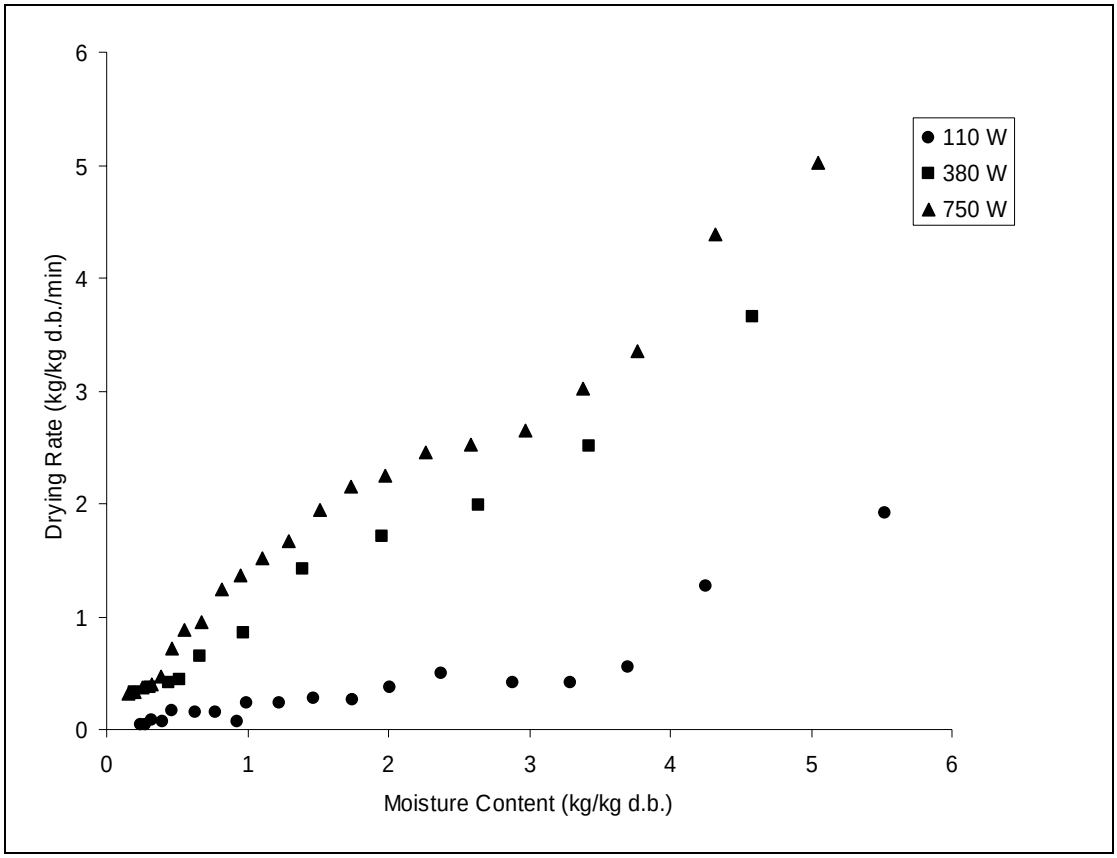



Fig. 4. Drying rate curves for different microwave power intensities

### 4.1.2 Tray drying

#### 4.1.2.1 Experimental design and response value

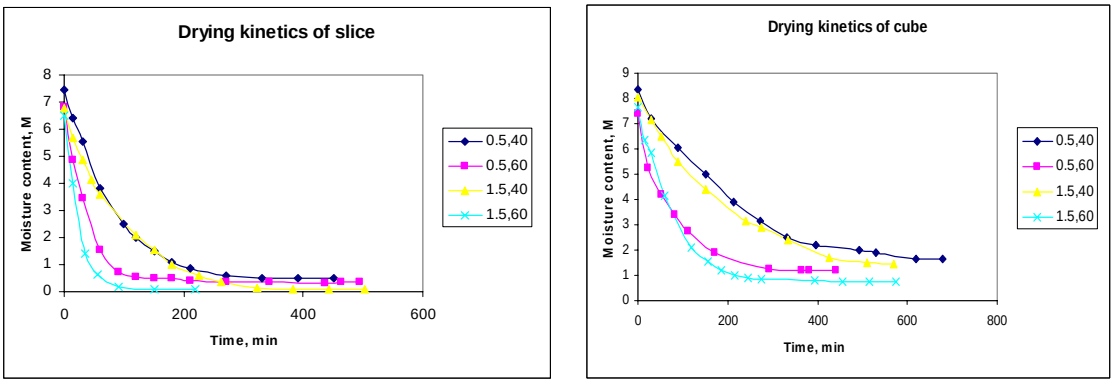
Table 2: Result of different runs of drying

| Run | | Independent variables | | | Dependent variables | |
|---|---|---|---|---|---|---|
| | Block | Geometry | Velocity (m/s) | Temperture (˚C) | Moisture content | Enzyme acticity (U/mg) |
| 1 | 1 | -1 | 0.5 | 40 | 0.4839 | 0.0041 |
| 2 | 1 | -1 | 0.5 | 60 | 0.3570 | 0.0037 |
| 3 | 1 | -1 | 1.5 | 40 | 0.0968 | 0.0040 |
| 4 | 1 | -1 | 1.5 | 60 | 0.08 | 0.0035 |
| 5 | 1 | 1 | 0.5 | 40 | 1.6349 | 0.0049 |
| 6 | 1 | 1 | 0.5 | 60 | 1.1818 | 0.0042 |
| 7 | 1 | 1 | 1.5 | 40 | 1.4444 | 0.0046 |
| 8 | 1 | 1 | 1.5 | 60 | 0.7302 | 0.0036 |
| 12 | 2 | -1 | 0.11808 | 50 | 0.5013 | 0.0047 |
| 13 | 2 | 1 | 1.88192 | 50 | 0.6981 | 0.0043 |
| 14 | 2 | -1 | 1 | 32.3617 | 0.7583 | 0.0080 |
| 15 | 2 | 1 | 1 | 67.6383 | 0.2154 | 0.00033 |

The range of different parameters (geometry, velocity and temperature) for the drying process of papaya fruit tea is shown in Table 2 along with the value of response (moisture content and enzyme activity).

### 4.1.2.2 Drying kinetics of fresh papaya

**a) Effect of temperature and air velocity**



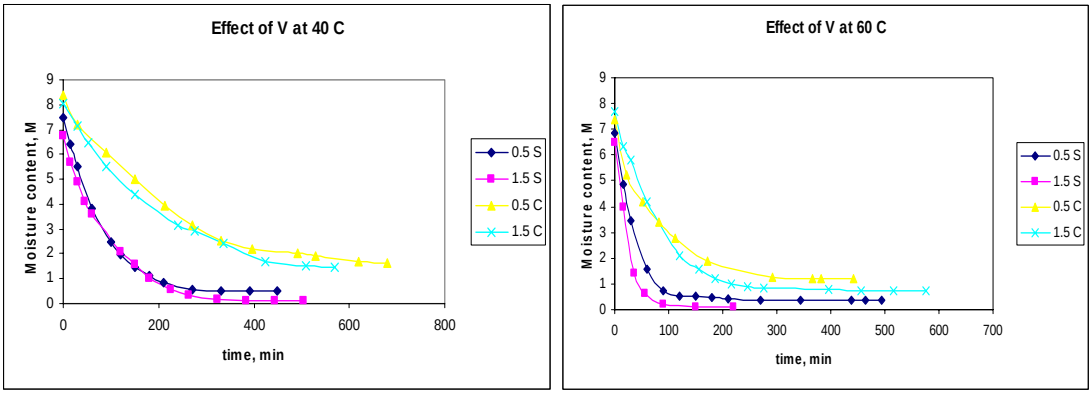

(a) (b)

Fig 4.1: Drying kinetics of (a) slice and (b) cube

Figure 4.1 represented the drying kinetics of two types of geometry and showed the influences of air velocity and temperature towards moisture content and drying time. By observing, it seems like the air velocity did not markedly influenced the drying kinetics for either slice or cube. It can be clearly seen that increasing of temperature from 40 ˚C to 60 ˚C, caused the decreasing of moisture content. However, by increasing the air velocity from 0.5 m/s to 1.5 m/s, the drying curve was remained as the same pattern. According to drying mechanism of transport properties, it indicates that the temperature played important role for mass and heat transfer in the interphase between hot air and fruit surface. On the other hand, air velocity was only aiding the drying process. With this, it can be conclude that temperature is more significant on affecting drying rate than air velocity. This result was valid to both geometry of slice and cube.

At the early stage of drying process, the moisture content was rapidly decline but then the drying curves show some convergence at the final drying process as the equilibrium conditions are reached. It shows that the beginning of drying process, both of air velocity and air temperature strongly influenced drying rate, however close to the end of drying the air temperature had effect upon drying, which higher than air velocity. This was due to high internal resistance of fruit rather external of fruit that made the air velocity insignificantly affect the drying process.

**b) Effect of geometry of fruit cut**




(a) (b)

Fig 4.2: Effect of geometry for (a) 40 C and (b) 60 C

Figure 4.2 represents the drying kinetics of papaya at different temperature. Temperature once again profound to be the most influence factor compare to air velocity as it becomes more accentuated at 60 °C (b). This was according the less moisture retained at 60 °C compared to 40 °C for either slice or cube.

Comparing both graph, it can be seen clearly that slice geometry having rapid drying process and retained less moisture content than cube. Compared to cubic geometry with slow drying process and retained more moisture. This occurred for both temperature of 40 and 60 °C.

### 4.1.2.3 Response Surface Methodology of moisture content

**a) Effect of temperature and air velocity**

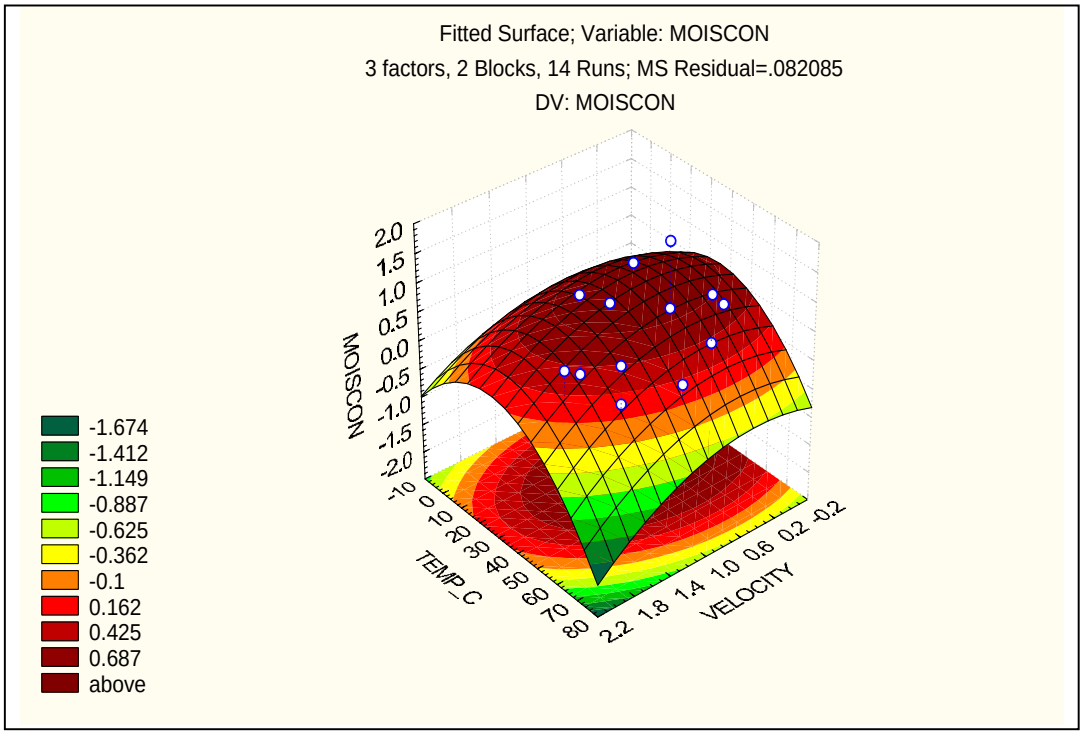



Figure 4.3: Response surface of moisture content versus air temperature and velocity.

The variation apparent of moisture content with duration of temperature and air velocity for the drying process at constant geometry is presented in figure 4.3. Referring to the 3-D graph of combination effect of both independent variables showed that temperature played most significant effect towards moisture content rather than air velocity. It is observed from the figure that the higher the temperature was, the lower moisture could be retained. These obey the theory, that the temperature mostly influenced the water loss. However air velocity still influenced the performance by restricting the drying process. From the observation, at higher air velocity of certain temperature would result in lower moisture content and faster drying rate. This is because air velocity was proved significantly in aiding the drying process. However, increasing more air velocity would decrease the drying rate and decreased water loss from sample. This phenomenon is caused by the decreasing distance of air through to attach fruit surface and less moisture could be carried away. Nevertheless slow velocity provides longer attachment between air and fruit surface, which provided more moisture to be carried away.

**b) Effect of geometry of fruit cut**

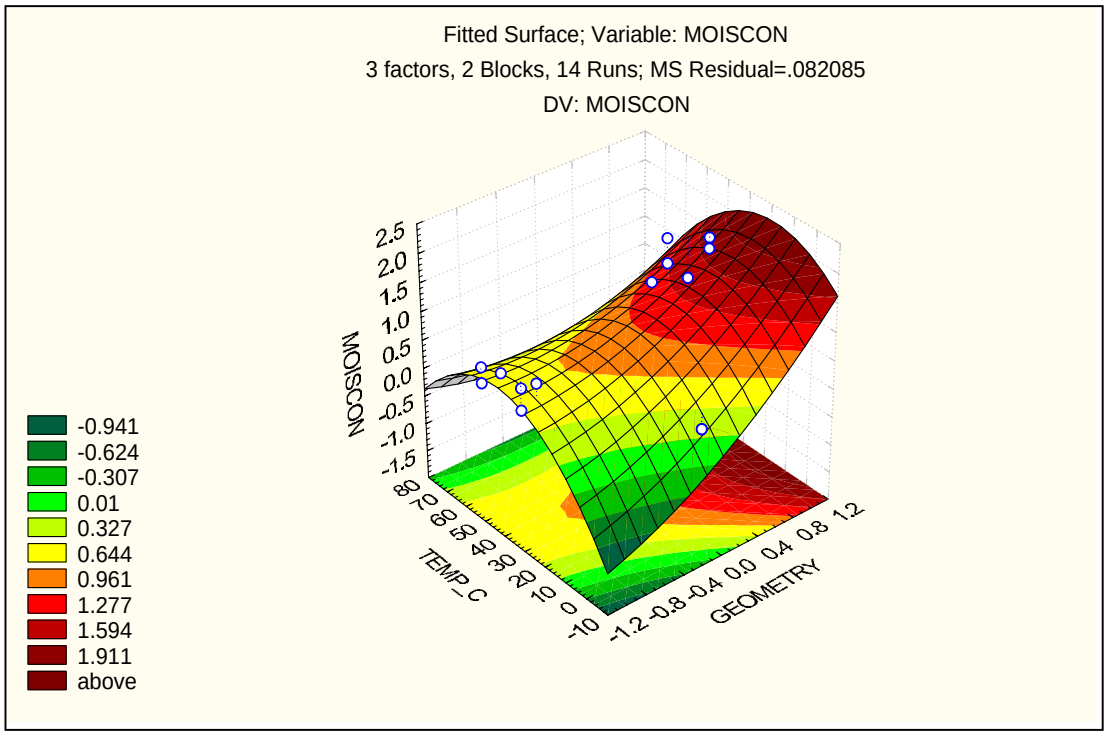



Figure 4.4: Response surface of moisture content versus temperature and geometry.

Figure 4.4 representing the response surface of moisture content on combination of two independent variables of air temperature and geometry. Referring to the graph, geometry of cutting fruit gave the most significant impact on moisture content rather than air temperature, which becomes insignificant for all analyzed samples. This would mean that retaining moisture content was still strongly depended on geometry of fruit cut. According to the graph, the lower the value of geometry (slice representing by -1), the lower the moisture content will be retained. This result showed that slice provided less moisture content than cube.

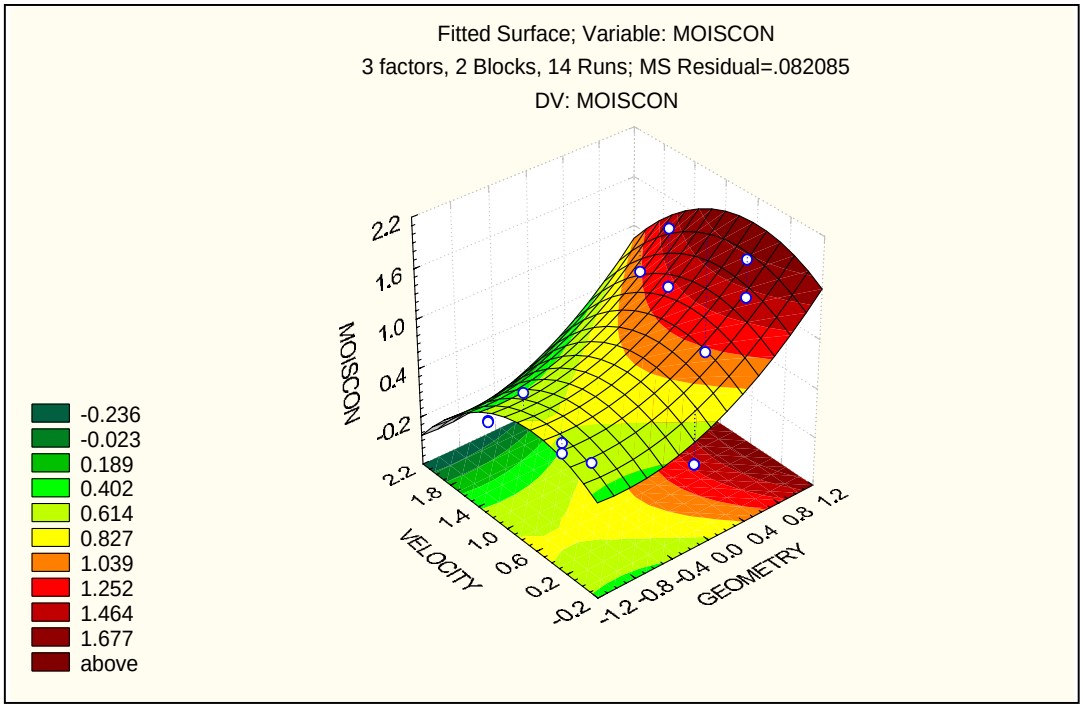



Figure 4.5: Response surface of moisture content versus air velocity and geometry.

Figure 4.5 consolidated statements above that geometry still plays most important part. According to 3-D graph presented above, geometry still controlling the effect on moisture content rather than air velocity that still proved that slice provided higher water loss than cubic geometry.

Table 3: Summary relation from response surface methodology

| **Figure** | **Relation of parameters and moisture content** | **Moisture content, Z** |
|---|---|---|
| | $Z = -1.2212\times10^{-15} + 0.69243V - 0.4264V^2 - 0.0038T - 0.00068T$ | 0.8986 |
| | $Z = -1.2212\times10^{-15} + 1.0664G + 0.2749G^2 + 0.0459T - 0.00068T^2$ $+ 0.0055(0.8571G) - 0.0128GT - 0.0038(0.857143T) + 0.2807$ | 1.7194 |
| | $Z = -1.221\times10^{-15} + 1.0664G + 0.2749G^2 + 0.6924V - 0.4264V^2 + 0.0055GV$ $- 0.0128(42.8571G) - 0.0038(42.8571V) + 0.7028$ | 1.6571 |

### 4.1.2.4 Analysis variance of moisture content

Table 4: ANOVA table

| | 3 factors, 2 Blocks, 14 Runs; MS Residual=.082085 DV: MOISCON | | | | |
|---|---|---|---|---|---|
| Factor | SS | df | MS | F | p |
| Blocks | 0.000000 | 1 | 0.000000 | 0.00000 | 1.000000 |
| (1)GEOMETRY(L) | 1.913048 | 1 | 1.913048 | 23.30569 | .016942 |
| GEOMETRY(Q) | .000050 | 1 | .000050 | .00061 | .981782 |
| (2)VELOCITY(L) | .399451 | 1 | .399451 | 4.86630 | .114531 |
| VELOCITY(Q) | .005341 | 1 | .005341 | .06507 | .815142 |
| (3)TEMP_C (L) | .931808 | 1 | .931808 | 11.35175 | .043435 |
| TEMP_C (Q) | .002222 | 1 | .002222 | .02707 | .879772 |
| 1L by 2L | .000060 | 1 | .000060 | .00074 | .980055 |
| 1L by 3L | .131014 | 1 | .131014 | 1.59607 | .295715 |
| 2L by 3L | .002855 | 1 | .002855 | .03478 | .863966 |
| Error | .246255 | 3 | .082085 | | |
| Total SS | 3.644701 | 13 | | | |

The result of the analysis of set of experimental data is displayed in Table A which is known as analysis of variance. The entries in the data table represent the sources that contribute to the total variation in the data values. ANOVA analysis was based on F value that is defined as the ratio of the mean square due to the real regression and the mean square due to real error. According to table above, F value that exceed p (probability) value will result in the rejection of nul hypothesis states that all of the coefficient, $b_i$ (excluding $b_o$) is zero which then implies that not all of the $b_i$ are zero. Hence, the contribution of F value from each source is equivalent to having the fitted model as below:

$$Z = 1.2212\times10^{-15} + 1.5890X_1 - 0.1619X_2 - 0.00324X_3 + 0.0055X_1X_2 + 0.00378X_2X_3 - 0.0128X_1X_3 + 0.9831$$

With:

Geometry ($X_1$)

Velocity ($X_2$)

Temperature ($X_3$)

Similarly, the value of accompanying statistics or quadratic regression ($R^2$) is 0.9324. This showed that 93.24% of the total variation is explained by the fitted model.

#### 4.1.2.5 Optimization from central composite design

**a) Optimum values**

The determination of optimum value is based on the critical value obtained from the model. The value expressed from the response surface as below.

Table 5: Optimum value for each parameter

| Factor | Observed minimum | Critical values | Observed maximum |
|---|---|---|---|
| Geometry | -1 | 0.99400 | 1 |
| Velocity (m/s) | 0.118080 | 0.62445 | 1.88192 |
| Temperature (˚C) | 32.36170 | 40.88942 | 67.63830 |

Therefore, optimum values are:

Geometry = 0.99400 ~ 1 (cube)

Velocity = 0.62445 ~ 0.5 m/s

Temperature = 40.88942 ~ 40 ˚C

#### 4.1.2.6 Enzyme analysis

Table 6: Enzyme concentration and enzyme activity

| Run | OD | Enzyme Concentration (mg/ml) | Enzyme acticity (U/mg) |
|---|---|---|---|
| 1 | 0.104 | 0.2047 | 0.0041 |
| 2 | 0.116 | 0.1836 | 0.0037 |
| 3 | 0.108 | 0.1977 | 0.0040 |
| 4 | 0.121 | 0.1748 | 0.0035 |
| 5 | 0.082 | 0.2434 | 0.0049 |
| 6 | 0.101 | 0.2100 | 0.0042 |
| 7 | 0.09 | 0.2293 | 0.0046 |
| 8 | 0.117 | 0.1819 | 0.0036 |
| 12 | 0.087 | 0.2346 | 0.0047 |
| 13 | 0.098 | 0.2153 | 0.0043 |
| 14 | -0.0074 | 0.4006 | 0.0080 |
| 15 | 0.211 | 0.0165 | 0.00033 |

### 4.1.2.7 Response Surface Methodology for enzyme activity

**a) Effect of temperature and air velocity**

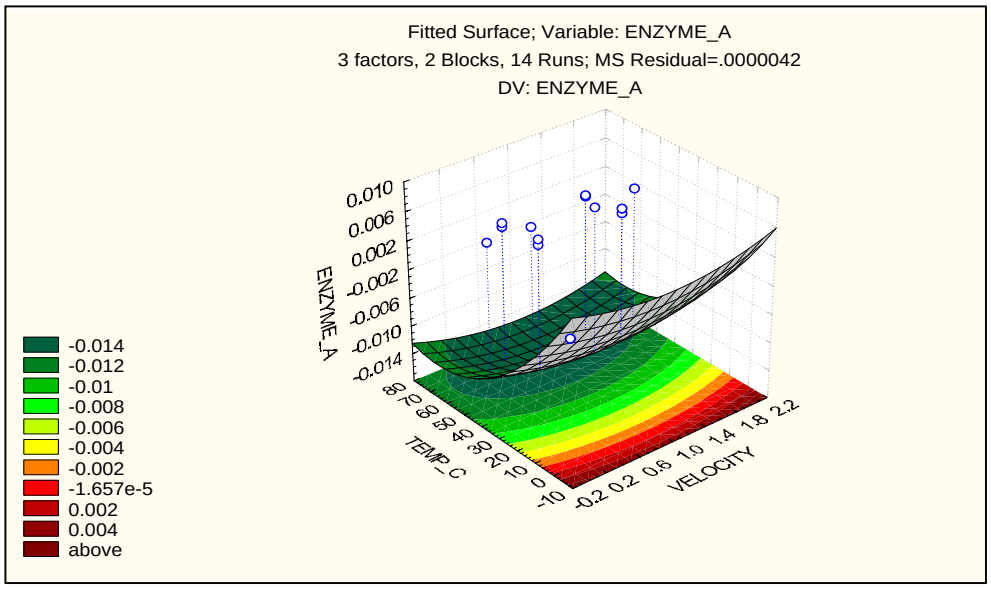



Fig 4.6: Response surface of enzyme activity versus air temperature and velocity.

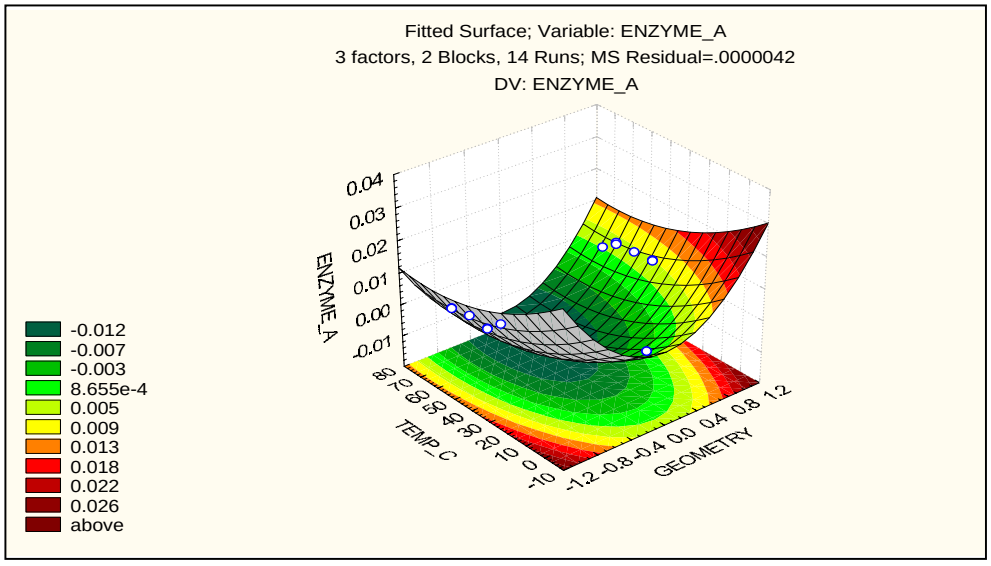



Figure 4.7: Response of enzyme activity versus temperature and geometry.

According to response surface of enzyme activity, it can be inferred that temperature exhibit as the tremendous effect compare to other independent variables such air velocity and geometry. Referring to figure 4.6, increasing of temperature result in the degradation on enzyme concentration in sample. Lower enzyme activity will be obtained since enzyme concentration is proportionate to enzyme activity. However air velocity seems not affect much on the enzyme retained. Hence, the surface exhibits a curvature shape.

This is due to the behavior of enzyme that sensitive to varying temperature and time. At low temperature, the drying process mostly influenced by air velocity and therefore, drying will not seriously damaging the enzymes inside and will only degrade some of it due to the time exposure. However, higher temperature will caused rapid degradation of the enzyme with concurrent and irreversible loss. Hence little amount of enzyme could only be retained.

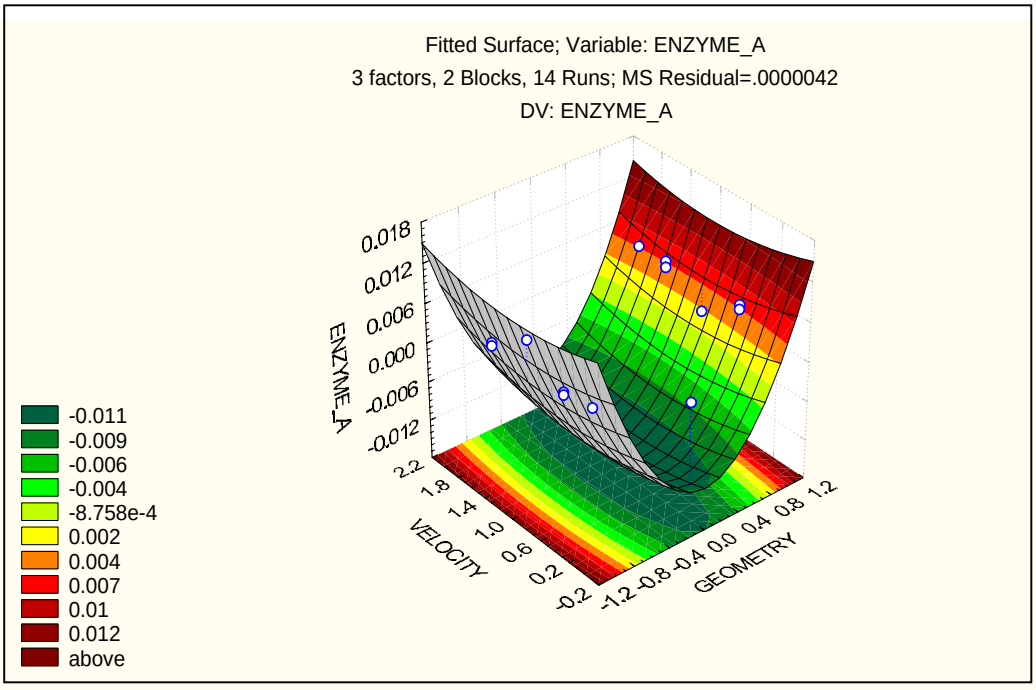



Figure 4.8: Response surface of enzyme activity versus velocity and geometry.

But, the degradation of enzyme is actually affecting by the geometry of cutting size of sample, which automatically influences the losses of enzyme. This due to surface exposure where larger surface area exposes to heat may increase the degradation of enzyme. Slice that provides thin breadth surface rather than cubic geometry will provide more surface to heat by temperature which contributed to the losses of enzyme. This explained the result obtained in table 6, where lower enzyme concentration obtained for slice compared to cube at same condition of temperature and air velocity.

Table 7: Summary relation from response surface methodology

| **Figure** | **Relation of parameters and moisture content** | **Moisture content, Z** |
|---|---|---|
| | $Z = -1.030\times10^{-18} - 0.00311V + 0.00166V^2 - 4.2624\times10^{-4}T + 3.2509\times10^{-6}T^2 - 7.9142\times10^{-6}TV$ | -0.0158 |
| | $Z = -1.030\times10^{-18} + 4.4174\times10^{-4}G + 0.0184G^2 - 4.2624\times10^{-4}T + 3.2509\times10^{-6}T^2 - 0.000132(0.85714G) - 9.2332\times10^{-6}TG - 7.9142\times10^{6}(0.85714T) - 0.00145$ | 0.0024 |
| | $Z = -1.030\times10^{-18} + 4.4174G + 0.0184G^2 - 0.00311V + 9.2332\times10^{-6}(42.8571G) - 7.9142\times10^{-6}(42.8571T) - 0.0123$ | 0.0042 |

### 4.1.2.8 Analysis variance of enzyme activity

Table 8: ANOVA table

| | 3 factors, 2 Blocks, 14 Runs; MS Residual=.0000042 DV: [ENZYME] | | | | |
|---|---|---|---|---|---|
| Factor | SS | df | MS | F | p |
| Blocks | 0.000000 | 1 | 0.000000 | 0.000000 | 1.000000 |
| (1)GEOMETRY(L) | .000000 | 1 | .000000 | .056728 | .827085 |
| GEOMETRY(Q) | .000000 | 1 | .000000 | .053962 | .831252 |
| (2)VELOCITY(L) | .000000 | 1 | .000000 | .026597 | .880817 |
| VELOCITY(Q) | .000000 | 1 | .000000 | .019466 | .897878 |
| (3)TEMP_C (L) | .000016 | 1 | .000016 | 3.742694 | .148494 |
| TEMP_C (Q) | .000000 | 1 | .000000 | .011929 | .919923 |
| 1L by 2L | .000000 | 1 | .000000 | .008355 | .932931 |
| 1L by 3L | .000000 | 1 | .000000 | .016376 | .906270 |
| 2L by 3L | .000000 | 1 | .000000 | .003008 | .959711 |
| Error | .000012 | 3 | .000004 | | |
| Total SS | .000061 | 13 | | | |

From table above, quadratic regression ($R^2$) was significant at level 0.7954 which also performing the correlation and interaction of observed response due to the experiment factor. Hence, the value considered acceptable yet unsatisfied which means that only 79.54% of total variation contributed by the fitted model. Hence, the contribution of F value from each source is equivalent to having the fitted model as below:

$$Z = -1.2010\times10^{-18} - 6.4282\times10^{-4}X_1 + 0.0367X_1^{\,2} - 3.3918\times10^{-4}X_2 - 6.784\times10^{-6}X_3$$
$$- 0.00013X_1X_2 - 9.233\times10^{-6}X_1X_3 + 7.9142\times10^{-6}X_2X_3 - 0.01374$$

With:

Geometry ($X_1$)

Velocity ($X_2$)

Temperature ($X_3$)

### 4.1.2.9 Optimization from central composite design

**a) Optimum values**

The determination of optimum value is based on the critical value obtained from the model. The value expressed from the response surface as below.

Table 9: Optimum value for each parameter

| Factor | Observed minimum | Critical values | Observed maximum |
|---|---|---|---|
| Geometry | -1 | 0.00873 | 1 |
| Velocity (m/s) | 0.118080 | 1.09597 | 1.88192 |
| Temperature (˚C) | 32.36170 | 66.90409 | 67.63830 |

Therefore, optimum values are:

Geometry = 0.00873~ 1 (cube)
Velocity = 1.09597~ 1.0 m/s
Temperature = 66.90409~ 60 ˚C

### 4.1.3 Osmotic dehydration

Response surface and methodology (RSM) is a set of technique design to find the best value of the response which generally is used for the following three steps:

(1) Design and collection of experimental data which allow fitting a general quadratic equation for smoothing and prediction
(2) Regression analysis to select the best equation for description of the data
(3) Examination of the fitted surface via contour plots and other graphical and numerical tools.

Response surface and methodology using experimental design was used for the optimizing of all variables. A second level design with four factors at three levels each was used in order to take into account the individual effects. The experimental design included 16 different treatments and three central points for the each geometry sample, totalling 22 experiments.

The study includes 22 experiments or run with four factors which are called independent variables. The independent variables studied were the geometry (slice and cube), lactic acid concentration (0, 0.05, 0.1M), sucrose concentration (40, 50, 60˚B) and temperature (30, 45, 60˚C). The dependent variables or the responses for this study are weight reduction (WR %), water loss (WL %), solid gain (SG %), enzyme concentration and enzyme activity.

Analysis of variance (ANOVA) was performed which factors and interactions are significant. Pareto chart will shows the effect estimate of the most important factor. P-values calculated by the program will be comparing with the F-ratios values to determine

which factors and interactions have significance effects. Data statistica analyses were performed using Statistica5.0 Software (Statsoft, 1997).

The goal at the stage of experimental design analysis is to describe in detail the relationship between the factor and the response. From the Table 1, we have decided to use a quadratic equation to describe the relationship between our response, Y, and the independent variables, $X_i$'s. The following polynomial model was fitted to the data:

$$Y = b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + b_{23}X_2X_3 + b_{24}X_2X_4 + b_{34}X_3X_4$$

Where $b_n$ are constant regression coefficients; Y is the predicted response (percentage of WL, WR,SG and enzyme activity(%)); $X_1$, $X_2$, $X_3$ and $X_4$ are geometry (slice or cube), lactic acid concentration (M), sucrose concentration (˚Brix) and temperature (˚C) respectively.

| TEXT VALUES | 2**(4) central composite, nc=16 ns=8 nc0=1 ns0=1 Runs=22 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 BLOCK | 2 GEOMETRY | 3 LAC.CON | 4 SUC.CON | 5 TEMP_D | 6 WR_% | 7 WL_% | 8 SG_% | 9 ENZY.CON | 10 ENZYME_A |
| 1 | 1 | Slice | 0.0000 | 40.0000 | 30.0000 | 48.6076 | 58.3473 | 9.7397 | .2593 | .0041 |
| 2 | 1 | Slice | 0.0000 | 40.0000 | 60.0000 | 14.2112 | 22.8389 | 8.6277 | .2668 | .0027 |
| 3 | 1 | Slice | 0.0000 | 60.0000 | 30.0000 | 47.5026 | 59.9595 | 12.4569 | .2450 | .0037 |
| 4 | 1 | Slice | 0.0000 | 60.0000 | 60.0000 | 11.2943 | 33.1472 | 21.8529 | .2935 | .0030 |
| 5 | 1 | Slice | .1000 | 40.0000 | 30.0000 | 55.6673 | 57.1184 | 1.4512 | .2481 | .0056 |
| 6 | 1 | Slice | .1000 | 40.0000 | 60.0000 | 61.6000 | 63.9073 | 2.3073 | .0808 | .0023 |
| 7 | 1 | Slice | .1000 | 60.0000 | 30.0000 | 68.4333 | 68.6303 | .1970 | .2350 | .0074 |
| 8 | 1 | Slice | .1000 | 60.0000 | 60.0000 | 49.5165 | 55.4708 | 5.9544 | .0864 | .0021 |
| 9 | 1 | Cube | 0.0000 | 40.0000 | 30.0000 | 5.6391 | 23.2033 | 17.5642 | .2381 | .0008 |
| 10 | 1 | Cube | 0.0000 | 40.0000 | 60.0000 | 9.4628 | 23.9017 | 14.4389 | .0907 | .0004 |
| 11 | 1 | Cube | 0.0000 | 60.0000 | 30.0000 | 22.7523 | 59.6275 | 36.8752 | .2114 | .0009 |
| 12 | 1 | Cube | 0.0000 | 60.0000 | 60.0000 | 12.0604 | 30.5399 | 18.4795 | .0982 | .0004 |
| 13 | 1 | Cube | .1000 | 40.0000 | 30.0000 | 19.5685 | 58.4894 | 38.9209 | .3781 | .0013 |
| 14 | 1 | Cube | .1000 | 40.0000 | 60.0000 | 14.6764 | 24.9529 | 10.2764 | .3172 | .0013 |
| 15 | 1 | Cube | .1000 | 60.0000 | 30.0000 | 41.5512 | 68.6856 | 27.1344 | .3364 | .0016 |
| 16 | 1 | Cube | .1000 | 60.0000 | 60.0000 | 11.8595 | 24.8332 | 12.9737 | .3520 | .0015 |
| 17 | 1 | slice | 0.0000 | 50.0000 | 45.0000 | 18.6665 | 26.2215 | 7.5550 | .3557 | .0049 |
| 18 | 2 | slice | .1529 | 50.0000 | 45.0000 | 30.1207 | 40.5848 | 10.4641 | .3470 | .0054 |
| 19 | 2 | slice | .0500 | 29.4202 | 45.0000 | 16.0831 | 56.8788 | 40.7957 | .3508 | .0031 |
| 20 | 2 | Cube | .0500 | 70.5798 | 45.0000 | 21.9254 | 31.1291 | 9.2037 | .3651 | .0016 |
| 21 | 2 | Cube | .0500 | 50.0000 | 14.1303 | 26.8819 | 32.5665 | 5.6846 | .2655 | .0013 |
| 22 | 2 | Cube | .0500 | 50.0000 | 75.8679 | 20.3396 | 22.5143 | 2.1747 | .0001 | .0000 |

Table 10 : Experimental design and observed values of response variables.

### 4.1.3.1 Enzyme Activity Analysis Using Experimental Design

| TEXT VALUES | 2**(4) central composite, nc=16 ns=8 nc0=1 ns0=1 Runs=22 | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 BLOCK | 2 GEOMETRY | 3 LAC.CON | 4 SUC.CON | 5 TEMP_D | ENZYME_A | PREDICTED |
| 1 | 1 | Slice | 0.000000 | 40.00000 | 30.00000 | .004109 | 0.0042 |
| 2 | 1 | Slice | 0.000000 | 40.00000 | 60.00000 | .002715 | 0.0024 |
| 3 | 1 | Slice | 0.000000 | 60.00000 | 30.00000 | .003706 | 0.0045 |
| 4 | 1 | Slice | 0.000000 | 60.00000 | 60.00000 | .002955 | 0.0023 |
| 5 | 1 | Slice | .100000 | 40.00000 | 30.00000 | .005634 | 0.0057 |
| 6 | 1 | Slice | .100000 | 40.00000 | 60.00000 | .002335 | 0.0025 |
| 7 | 1 | Slice | .100000 | 60.00000 | 30.00000 | .007448 | 0.0065 |
| 8 | 1 | Slice | .100000 | 60.00000 | 60.00000 | .002129 | 0.0029 |
| 9 | 1 | Cube | 0.000000 | 40.00000 | 30.00000 | .000789 | 0.0004 |
| 10 | 1 | Cube | 0.000000 | 40.00000 | 60.00000 | .000350 | 0.0009 |
| 11 | 1 | Cube | 0.000000 | 60.00000 | 30.00000 | .000918 | 0.0005 |
| 12 | 1 | Cube | 0.000000 | 60.00000 | 60.00000 | .000404 | 0.0006 |
| 13 | 1 | Cube | .100000 | 40.00000 | 30.00000 | .001296 | 0.0017 |
| 14 | 1 | Cube | .100000 | 40.00000 | 60.00000 | .001306 | 0.0007 |
| 15 | 1 | Cube | .100000 | 60.00000 | 30.00000 | .001582 | 0.0023 |
| 16 | 1 | Cube | .100000 | 60.00000 | 60.00000 | .001473 | 0.0009 |
| 17 | 1 | slice | 0.000000 | 50.00000 | 45.00000 | .004937 | 0.0049 |
| 18 | 2 | slice | .152899 | 50.00000 | 45.00000 | .005433 | 0.0054 |
| 19 | 2 | slice | .050000 | 29.42020 | 45.00000 | .003075 | 0.0031 |
| 20 | 2 | Cube | .050000 | 70.57980 | 45.00000 | .001589 | 0.0016 |
| 21 | 2 | Cube | .050000 | 50.00000 | 14.13030 | .001299 | 0.0011 |
| 22 | 2 | Cube | .050000 | 50.00000 | 75.86790 | .000000 | 0.0002 |

Table 11: The Experimental and Theoretical Predicted Values

Table 11 shows the result of experimental and theoretical predicted values for papain enzyme activity. The predicted response calculated by the program and the graph observed versus predicted values shown in the Graph 4.9. Our goals is to find the best values for the constant in the models which is the values of constant that give the best fit to set of data. A good fit of the line to the data means that the line should be as close to all the data points as possible.

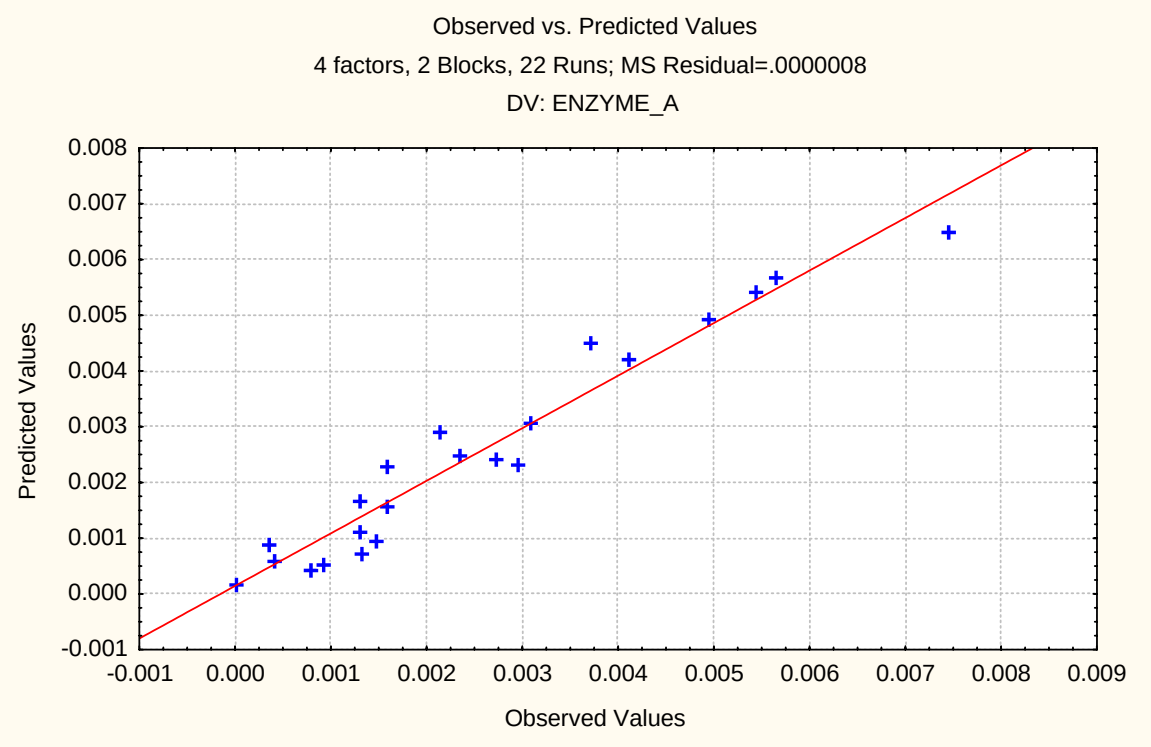



Figure 4.9 : Graph Observed vs. Predicted Values for Enzyme Activity Response

$R^2$ is the fraction of the total variability in the data that is explained by the model which is useful indicator of how closely the regression equation matches the data. The quadratic regression ($R^2$) was significant at level of 0.919, which is considered high, since the $R^2$ values provides a measure of the variability of the observe response due to the experiment factor and their interaction. The value of $R^2$ is measured the total variation of observed value about the mean obtained by the fitted model or correlation between the observed and predicted value from the result.

| Factor | 4 factors, 2 Blocks, 22 Runs; MS Residual=.0000008 DV: ENZYME_A | | | | | |
|---|---|---|---|---|---|---|
| | Regressn Coeff. | Std.Err. | t(6) | p | -95.% Cnf.Limt | +95.% Cnf.Limt |
| Mean/Interc. | 23.11678 | 12.34399 | 1.87271 | .110263 | -7.08789 | 53.32144 |
| BLOCK(1) | .00066 | .00077 | .86331 | .421132 | -.00122 | .00255 |
| (1)GEOMETRY(L) | -.45477 | .24368 | -1.86625 | .111255 | -1.05103 | .14149 |
| GEOMETRY(Q) | .00223 | .00120 | 1.85641 | .112783 | -.00071 | .00518 |
| (2)LAC.CON (L) | .23946 | .85665 | .27953 | .789228 | -1.85669 | 2.33560 |
| LAC.CON (Q) | -.04884 | .30352 | -.16092 | .877438 | -.79153 | .69385 |
| (3)SUC.CON (L) | .00159 | .00475 | .33567 | .748548 | -.01003 | .01321 |
| SUC.CON (Q) | -.00001 | .00001 | -.94639 | .380487 | -.00002 | .00001 |
| (4)TEMP_D (L) | -.00720 | .00255 | -2.82130 | .030302 | -.01345 | -.00096 |
| TEMP_D (Q) | -.00000 | .00000 | -1.02079 | .346737 | -.00001 | .00000 |
| 1L by 2L | -.00216 | .00877 | -.24657 | .813458 | -.02361 | .01929 |
| 1L by 3L | -.00001 | .00004 | -.23079 | .825147 | -.00012 | .00010 |
| 1L by 4L | .00007 | .00003 | 2.96241 | .025204 | .00001 | .00014 |
| 2L by 3L | .00026 | .00044 | .58266 | .581340 | -.00082 | .00133 |
| 2L by 4L | -.00047 | .00029 | -1.60216 | .160240 | -.00118 | .00025 |
| 3L by 4L | -.00000 | .00000 | -.44800 | .669879 | -.00000 | .00000 |

Table 12: Regression Analysis for Enzyme Activity, Quadratic Response Surface Model Fitting (Predicted Value).

From Table 12, the regression equation obtained after analysis of variance give the level of panels response as a function of the independent variables of the geometry (slice or cube), lactic acid concentration (M), sucrose concentration (˚Brix) and temperature (˚C). All terms regardless of their significance are included in the quadratic equation below describing the relationship between independent variables to the response:

$$Y = 23.11678 - 0.45477X_1 + 0.00223X_1^2 + 0.23946X_2 - 0.04884X_2^2 + 0.00159X_3 - 0.00001X_3^2$$
$$- 0.0072X_4 - 0.00216X_1X_2 - 0.00001X_1X_3 + 0.00007X_1X_4 + 0.00026X_2X_3 - 0.00047X_2X_4$$

The standard error provides an indication of the “accuracy” of the point estimate of standard deviation. Smaller of the standard error indicate that the point estimate is likely to be more accurate because its variability about true value of probability (p) is smaller.

Optimum or critical values are obtained from this equation. The values for the coefficient of the model are obtained from the response surface methodology calculation.

| Factor | Solution: saddlepoint<br>Predicted value at solution: .0028617 | | |
|---|---|---|---|
| | Observed Minimum | Critical Values | Observed Maximum |
| GEOMETRY | 100.0000 | 101.3327 | 102.0000 |
| LAC.CON | 0.0000 | .1700 | .1529 |
| SUC.CON | 29.4202 | 53.6658 | 70.5798 |
| TEMP_D | 14.1303 | 37.4810 | 75.8679 |

Table 13 : Optimum Value for each Parameter

From the model, the optimum values are:

Geometry (slice or cube) = 101.3327

Lactic acid concentration = 0.1700 M

Sucrose concentration = 53.6658 ˚Brix

Temperature = 37.4810 ˚C

The result of the analysis of a set of experimental data can be displayed in table form known as the *analysis of variance table*. The analysis of variance table displaying the total, regression (SS), and residual sums of squares (MS) as shown in Table 14. The entries in the table represent sources that contribute to the total variation in the data values. The total variation in the data values is called the “total sum of squares”. Total sum of square is the sum of two quantities; the sum of square due to the regression (SS) and sum of squares of the residuals (MS). The quantity of total sum of square has associated with it N-1 degree of freedom (df) with N is the total number of observations collected.

| Factor | SS | df | MS | F | p |
|---|---|---|---|---|---|
| 4 factors, 2 Blocks, 22 Runs; MS Residual=.0000008 DV: ENZYME_A | | | | | |
| Blocks | .000001 | 1 | .000001 | .745300 | .421132 |
| (1)GEOMETRY(L) | .000000 | 1 | .000000 | .313737 | .595674 |
| GEOMETRY(Q) | .000003 | 1 | .000003 | 3.446272 | .112783 |
| (2)LAC.CON (L) | .000000 | 1 | .000000 | .205008 | .666620 |
| LAC.CON (Q) | .000000 | 1 | .000000 | .025895 | .877438 |
| (3)SUC.CON (L) | .000000 | 1 | .000000 | .197472 | .672349 |
| SUC.CON (Q) | .000001 | 1 | .000001 | .895654 | .380487 |
| (4)TEMP_D (L) | .000002 | 1 | .000002 | 2.823409 | .143899 |
| TEMP_D (Q) | .000001 | 1 | .000001 | 1.042008 | .346737 |
| 1L by 2L | .000000 | 1 | .000000 | .060798 | .813458 |
| 1L by 3L | .000000 | 1 | .000000 | .053263 | .825147 |
| 1L by 4L | .000007 | 1 | .000007 | 8.775894 | .025204 |
| 2L by 3L | .000000 | 1 | .000000 | .339498 | .581340 |
| 2L by 4L | .000002 | 1 | .000002 | 2.566911 | .160240 |
| 3L by 4L | .000000 | 1 | .000000 | .200700 | .669879 |
| Error | .000005 | 6 | .000001 | | |
| Total SS | .000081 | 21 | | | |

Table 14 : Regression Analysis for Enzyme Activity, Quadratic Response Surface Model Fitting (ANOVA)

In addition to computing the sums of squares, mean squares, and F-ratios the Statistica's program also computes a P-value, which is area under the F-Distribution density to the right of the calculated F-ratios.

$$F = \frac{\text{MS Due to Regression}}{\text{MS Residual}}$$
$$= \frac{38.3049}{99.9247}$$
$$= 0.3833$$

P-values calculated by the program will be comparing with the F-ratios values to determine which factors and interactions have significance effects. When the P-value for a particular factor is smaller than F-values, the factors was significant.

The Pareto chart from Figure 4.10 shows the ANOVA standardized effect estimates sorted by their absolute size to indicate the minimum magnitude of statistically significant effects.

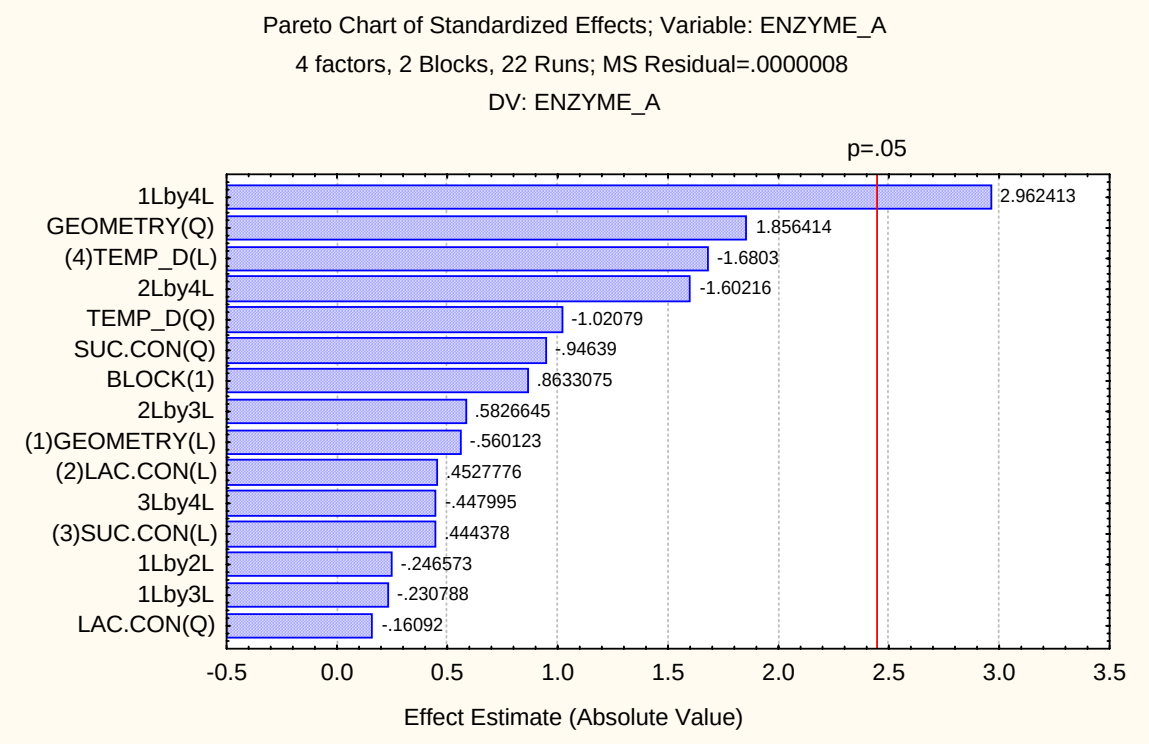



Figure 4.10: Pareto Chart of Effect of Variables for Experimental Design of Enzyme Activity.

The Pareto chart shows the effect estimate of the most important factor. In this case, the most important factor is the interaction between temperature and geometry, followed by geometry, temperature and sucrose concentration respectively. Lactic acid concentration shows the least significant effect to the experiment. From this result, we can decide that temperature and geometry is the most important factor and helps to increase enzymatic activity in the product.

The result from the Pareto chart was as in the theory which is temperature is the main factor affected to the enzyme.

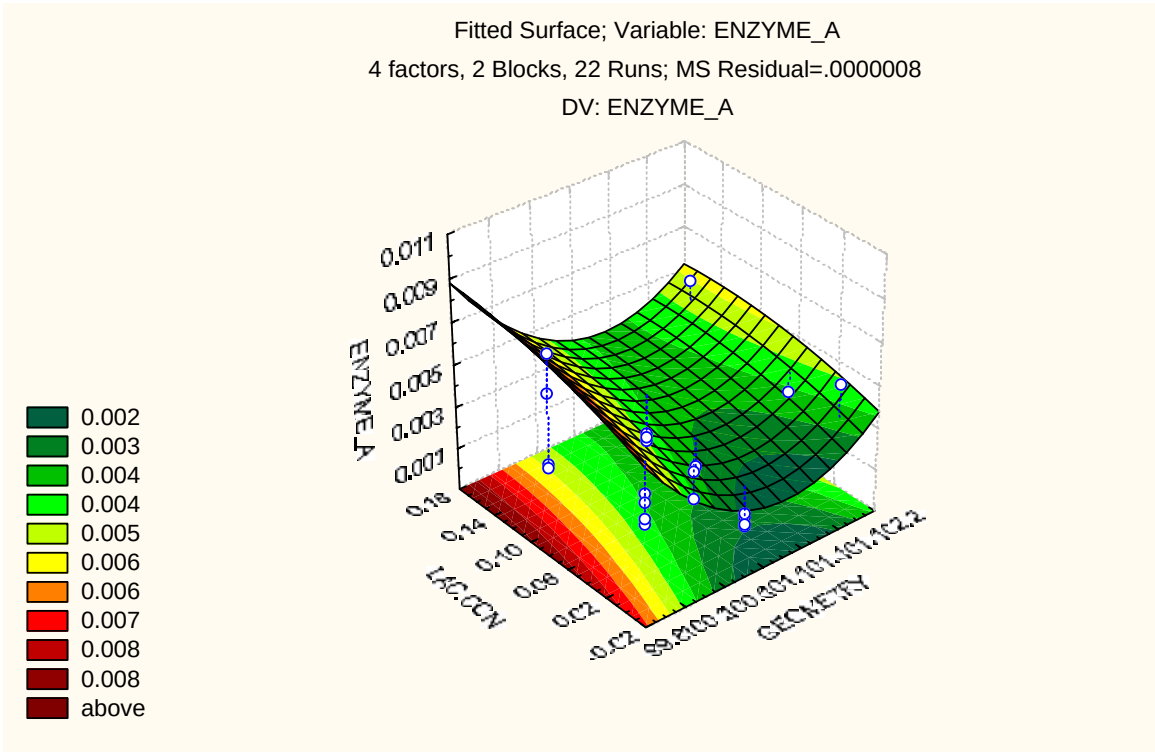



Figure 4.11 : Contour surface plot of enzyme activity value as function of the geometry and lactic acid concentration.

z=23.116776632396-.45476785054866*x+.0022346296357955*x^2
+.23945552580742*y-.048842617767441*y^2-.002161235099074*x*y
-.0000101144164406 81*53.6658*x+.00007459956851 6824*37.481*x
+.0002535568975708*53.6658*y-.0004681026787 2745*37.481*y
-.20602156

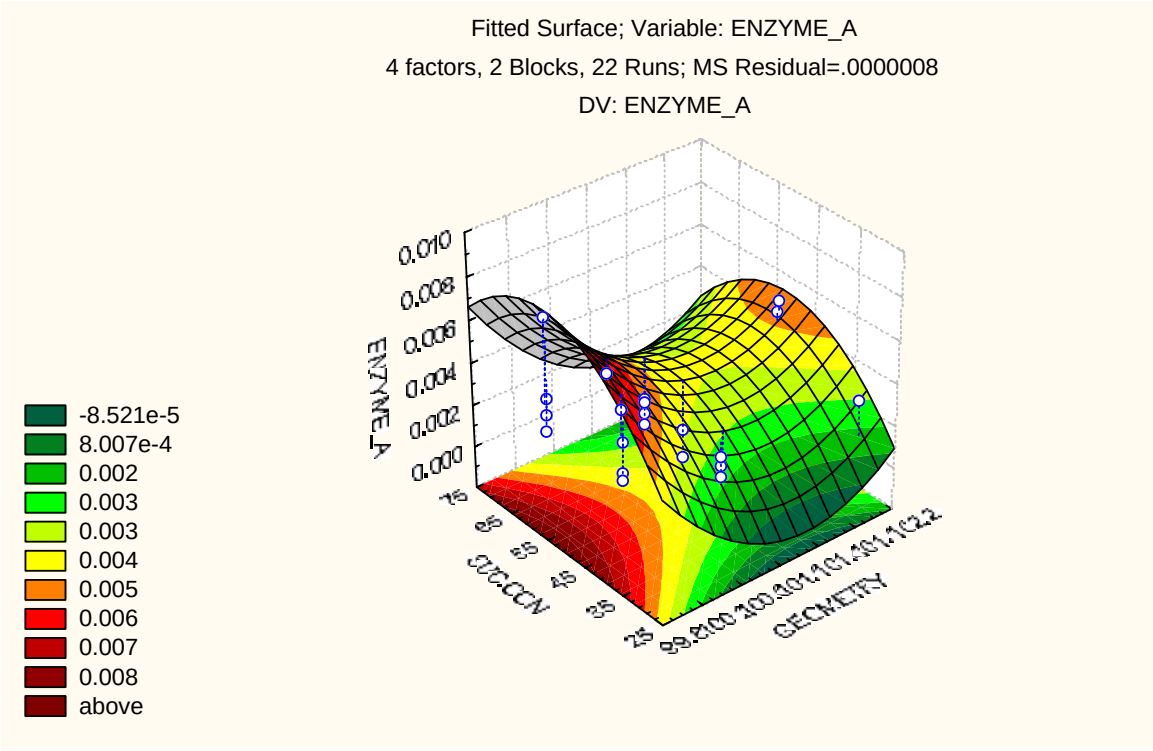



Figure 4.12 : Contour surface plot of enzyme activity value as function of the geometry and sucrose concentration.

z=23.116776632396-.45476785054866*x+.0022346296357955*x^2
+.0015939358894136*y-.0000054774839779093*y^2
-.002161235099074*.17*x-.00001011441644068 1*x*y
+.00007459956851682 4*37.481*x+.0002553556897570 8*.17*y
-.00000065445379077491*37.481*y-.2381565

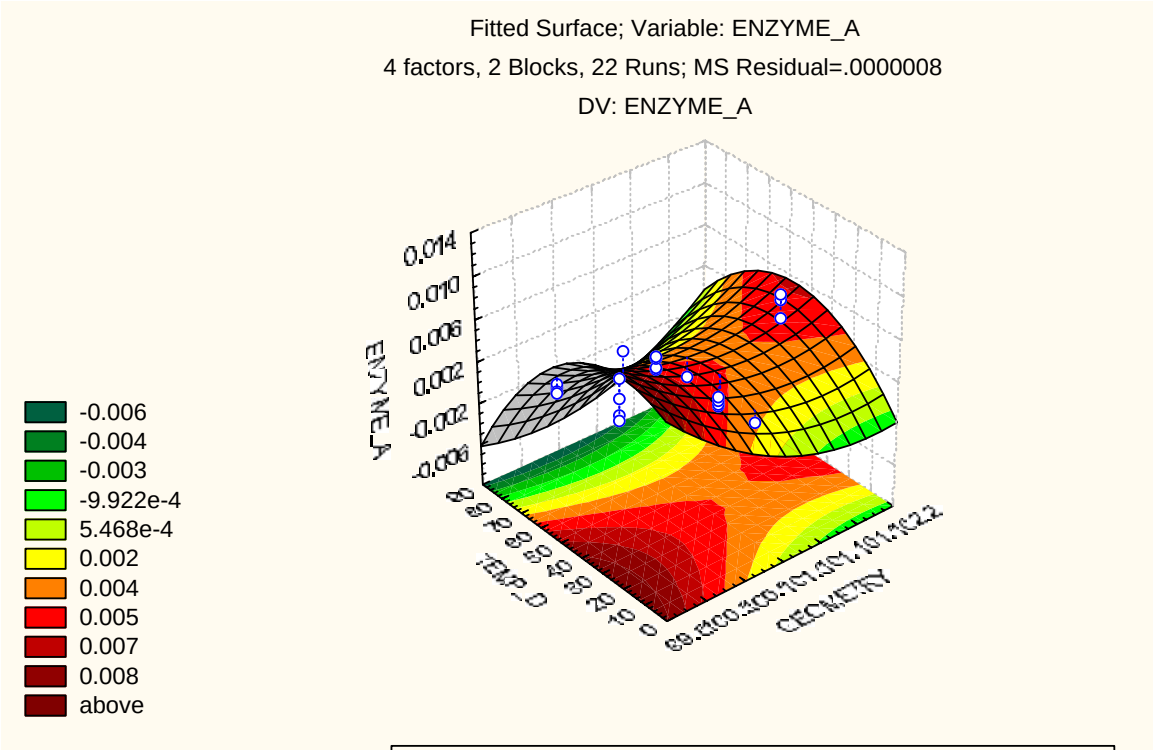



Figure 4.13 : Contour surface plot of enzyme activity value as function of the temperature and geometry.

z=23.116776632396-.45476785054866*x+.0022346296357955*x^2
-.0072011507232675*y-.0000032483884393514*y^2
-.002161235099074*.17*x-.0000101144164406 81*53.6658*x
+.00007459956851 6824*x*y-.00046810267872745*.17*y
-.0000065445379077491*53.6658*y+.111390137

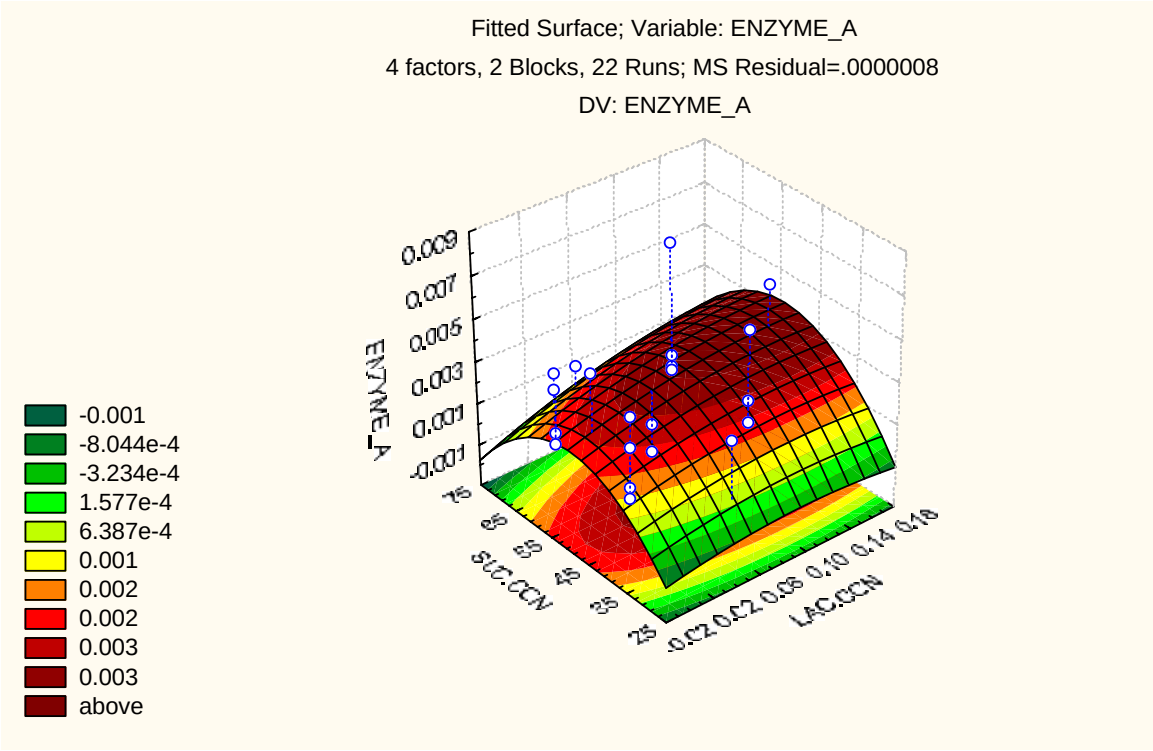



Figure 4.14 : Contour surface plot of enzyme activity value as function of the lactic acid concentration and sucrose concentration.

z=23.116776632396+.23945552580742*x-.048842617767441*x^2
+.0015939358894136*y-.0000054774839779093*y^2
-.002161235099074*101.3327*x-.00001011441644068 1*101.3327*y
+.00025535689757 08*x*y-.00046810267872745*37.481*x
-.00000654453790 77491*37.481*y-23.128108

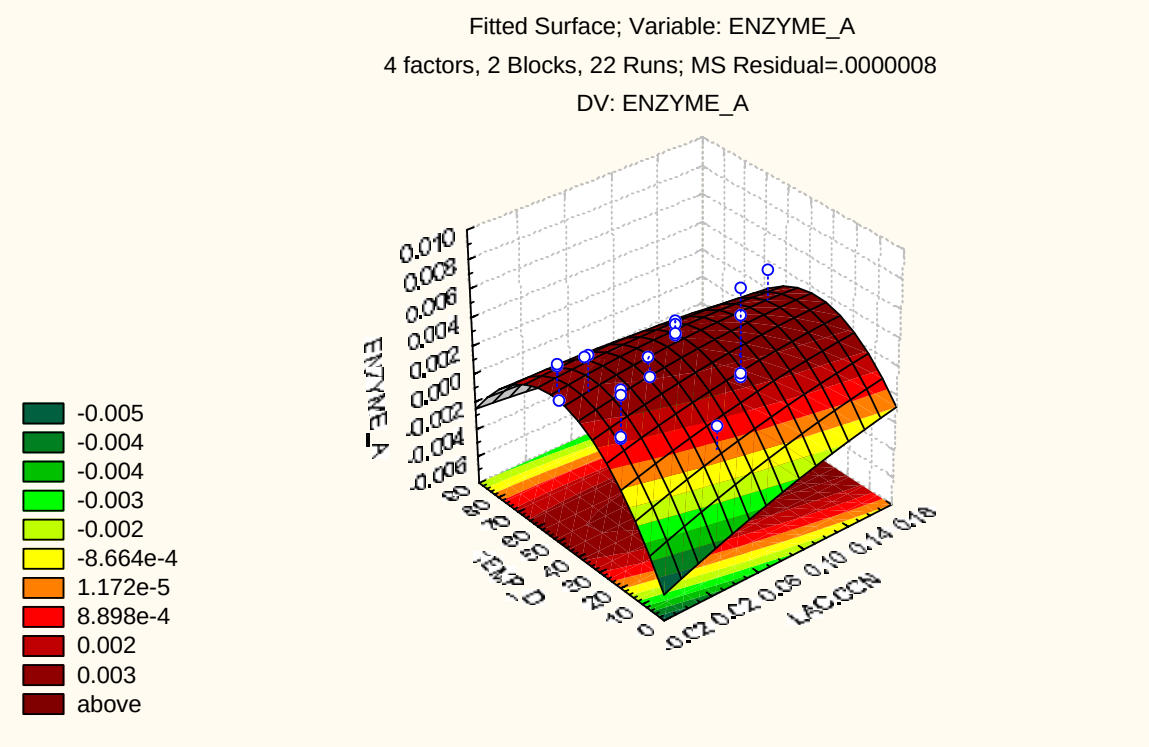



Figure 4.15 : Contour surface plot of enzyme activity value as function of the temperature and lactic acid concentration.

z=23.116776632396+.23945552580742*x-.048842617767441*x^2
-.0072011507232675*y-.0000032483884393514*y^2
-.002161235099074*101.3327*x+.00007459956851682 4*101.3327*y
+.00025535568975708*53.6658*x-.00046810267872745*x*y
-.00000654453790774 91*53.6658*y-23.122209

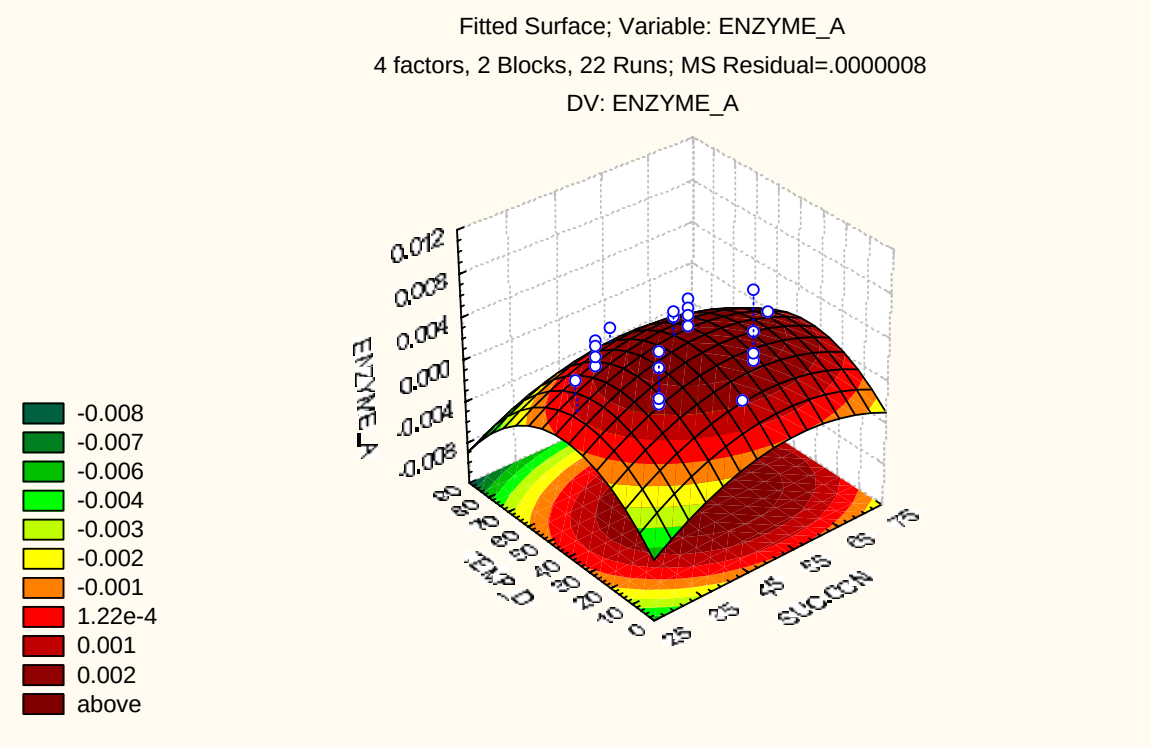



Figure 4.16 : Contour surface plot of enzyme activity value as function of the temperature and sucrose concentration.

Using the optimum value from the model:

Geometry (slice or cube) = 101.3327

Lactic acid concentration = 0.1700 M

Sucrose concentration = 53.6658 ˚Brix

Temperature = 37.4810 ˚C

We can calculate the optimum enzyme activity from one of the equation from the contour surface plot of enzyme activity value as function of the factors.

One of the models is Figure 4.16 that shows the contour surface plot of enzyme activity value as function of the temperature and sucrose concentration.

z = 23.116776632396 + .0015939358894136 * x - .0000054774839779093 * x^2
- .0072011507232675 * y - .0000032483884393514 * y^2
- .000010114416440681 * 101.3327 * x + .000074599568516824 * 101.3327 * y
+ .00025535568975708 * .17 * x - .00046810267872745 * .17 * y
- .000000654453790774 91 * x * y - 23.134905

**Sucrose concentration, X = 53.6658**

**Temperature, Y = 37.481**

**The optimum value for enzyme activity occurred at 0.003527 BU/mg**

### 4.1.3.2 Weight Reduction Analysis Using Experimental Design

| TEXT VALUES | 2**(4) central composite, nc=16 ns=8 nc0=1 ns0=1 Runs=26 | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 BLOCK | 2 GEOMETRY | 3 LAC.CON | 4 SUC.CON | 5 TEMP_D | 6 WR_% | PREDICTED |
| 1 | 1 | Slice | 0.00 | 40.00 | 30.00 | 48.61 | 39.28 |
| 2 | 1 | Slice | 0.00 | 40.00 | 60.00 | 14.21 | 22.89 |
| 3 | 1 | Slice | 0.00 | 60.00 | 30.00 | 47.50 | 46.17 |
| 4 | 1 | Slice | 0.00 | 60.00 | 60.00 | 11.29 | 13.29 |
| 5 | 1 | Slice | .10 | 40.00 | 30.00 | 55.67 | 63.42 |
| 6 | 1 | Slice | .10 | 40.00 | 60.00 | 61.60 | 54.51 |
| 7 | 1 | Slice | .10 | 60.00 | 30.00 | 68.43 | 71.35 |
| 8 | 1 | Slice | .10 | 60.00 | 60.00 | 49.52 | 45.94 |
| 9 | 1 | Cube | 0.00 | 40.00 | 30.00 | 5.64 | 8.96 |
| 10 | 1 | Cube | 0.00 | 40.00 | 60.00 | 9.46 | 6.80 |
| 11 | 1 | Cube | 0.00 | 60.00 | 30.00 | 22.75 | 26.40 |
| 12 | 1 | Cube | 0.00 | 60.00 | 60.00 | 12.06 | 7.75 |
| 13 | 1 | Cube | .10 | 40.00 | 30.00 | 19.57 | 14.14 |
| 14 | 1 | Cube | .10 | 40.00 | 60.00 | 14.68 | 19.45 |
| 15 | 1 | Cube | .10 | 60.00 | 30.00 | 41.55 | 32.62 |
| 16 | 1 | Cube | .10 | 60.00 | 60.00 | 11.86 | 21.45 |
| 17 | 2 | slice | 0.00 | 50.00 | 45.00 | 18.67 | 18.67 |
| 18 | 2 | slice | .15 | 50.00 | 45.00 | 30.12 | 30.12 |
| 19 | 2 | slice | .05 | 29.42 | 45.00 | 16.08 | 16.08 |
| 20 | 2 | Cube | .05 | 70.58 | 45.00 | 21.93 | 21.93 |
| 21 | 2 | Cube | .05 | 50.00 | 14.13 | 26.88 | 30.47 |
| 22 | 2 | Cube | .05 | 50.00 | 75.87 | 20.34 | 16.75 |

Table 15: The Experimental and Theoretical Predicted Values

Table 15 shows the result of experimental and theoretical predicted values for weight reduction, WR(%). The predicted response calculated by the program and the graph observed versus predicted values shown in the Figure 4.12. Our goals is to find the best values for the constant in the models which is the values of constant that give the best fit to set of data. A good fit of the line to the data means that the line should be as close to all the data points as possible.

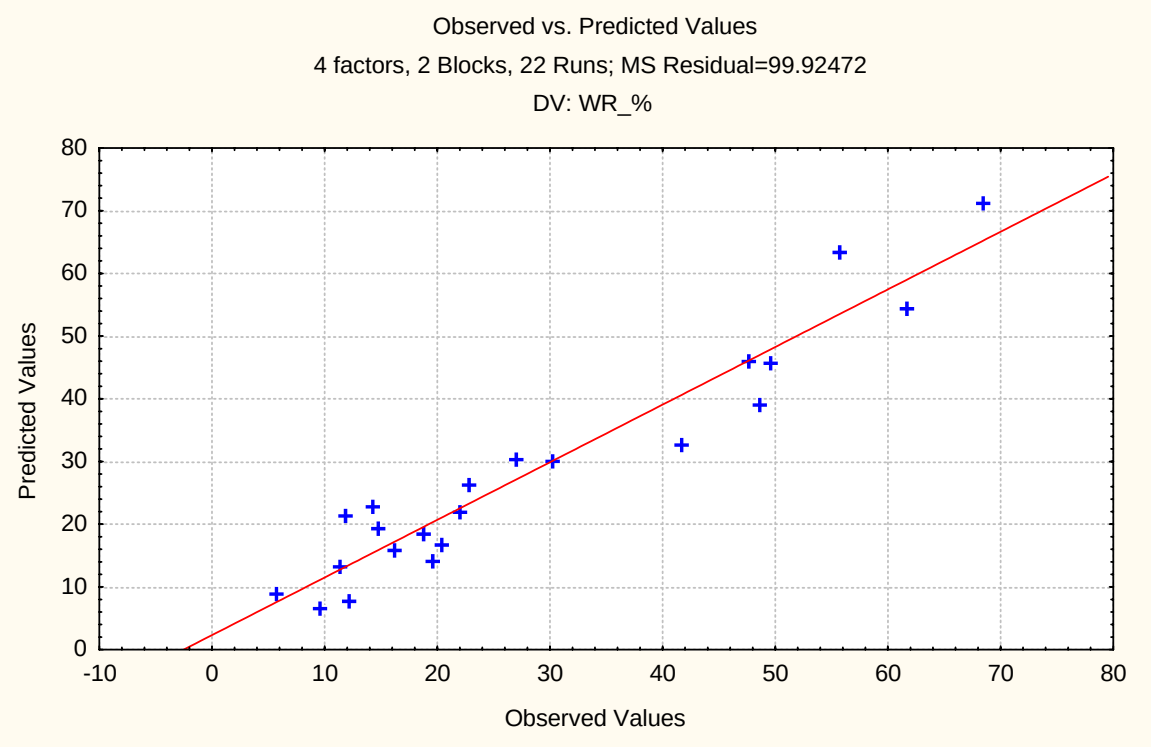



Figure 4.17 : Graph Observed vs. Predicted Values for Weight Reduction Response

$R^2$ is the fraction of the total variability in the data that is explained by the model which is useful indicator of how closely the regression equation matches the data. Figure 4.17 shows that the quadratic regression ($R^2$) was significant at level of 0.919, which is considered high, since the $R^2$ values provides a measure of the variability of the observe response due to the experiment factor and their interaction. The value of $R^2$ is measured the total variation of observed value about the mean obtained by the fitted model or correlation between the observed and predicted value from the result.

| Factor | 4 factors, 2 Blocks, 22 Runs; MS Residual=99.92472 DV: WR_% | | | | | |
|---|---|---|---|---|---|---|
| | Regressn Coeff. | Std.Err. | t(6) | p | -95.% Cnf.Limt | +95.% Cnf.Limt |
| Mean/Interc. | 271568.0 | 140778.1 | 1.92905 | .101978 | -72903.6 | 616039.7 |
| BLOCK(1) | -5.4 | 8.8 | -.61914 | .558583 | -26.9 | 16.0 |
| (1)GEOMETRY(L) | -5334.3 | 2779.1 | -1.91945 | .103344 | -12134.4 | 1465.8 |
| GEOMETRY(Q) | 26.2 | 13.7 | 1.90938 | .104798 | -7.4 | 59.8 |
| (2)LAC.CON (L) | 18788.6 | 9769.7 | 1.92314 | .102818 | -5117.1 | 42694.3 |
| LAC.CON (Q) | 3217.4 | 3461.5 | .92947 | .388510 | -5252.7 | 11687.4 |
| (3)SUC.CON (L) | -58.9 | 54.2 | -1.08827 | .318247 | -191.4 | 73.6 |
| SUC.CON (Q) | .1 | .1 | 1.11185 | .308756 | -.1 | .2 |
| (4)TEMP_D (L) | -50.9 | 29.1 | -1.74923 | .130830 | -122.1 | 20.3 |
| TEMP_D (Q) | .0 | .0 | 1.23670 | .262409 | -.0 | .1 |
| 1L by 2L | -189.6 | 100.0 | -1.89716 | .106589 | -434.2 | 55.0 |
| 1L by 3L | .5 | .5 | 1.05571 | .331743 | -.7 | 1.8 |
| 1L by 4L | .5 | .3 | 1.65162 | .149702 | -.2 | 1.2 |
| 2L by 3L | .5 | 5.0 | .10402 | .920543 | -11.7 | 12.7 |
| 2L by 4L | 2.5 | 3.3 | .74791 | .482789 | -5.7 | 10.6 |
| 3L by 4L | -.0 | .0 | -1.65004 | .150028 | -.1 | .0 |

Table 16: Regression Analysis for Weight Reduction, Quadratic Response Surface Model Fitting (Predicted Value).

From Table 16, the regression equation obtained after analysis of variance give the level of panels response as a function of the independent variables of the geometry (slice or cube), lactic acid concentration (M), sucrose concentration (˚Brix) and temperature (˚C). All terms regardless of their significance are included in the quadratic equation below describing the relationship between independent variables to the response:

$$Y = 271568.0 - 5334.3X_1 + 26.2X_1^2 + 18788.6X_2 + 3217.4X_2^2 - 58.9X_3 + 0.1X_3^2 - 50.9X_4 - 189.6X_1X_2 + 0.5X_1X_3 + 0.5X_1X_4 + 0.5X_2X_3 + 2.5X_2X_4$$

The standard error provides an indication of the accuracy of the point estimate of standard deviation. Smaller of the standard error indicate that the point estimate is likely to be more accurate because its variability about true value of probability (p) is smaller.

| Factor | Solution: minimum<br>Predicted value at solution: -9.94194 | | |
|---|---|---|---|
| | Observed Minimum | Critical Values | Observed Maximum |
| GEOMETRY | 100.0000 | 100.9717 | 102.0000 |
| LAC.CON | 0.0000 | .0339 | .1529 |
| SUC.CON | 29.4202 | 47.2674 | 70.5798 |
| TEMP_D | 14.1303 | 47.2369 | 75.8679 |

Table 17 : Optimum Value for each Parameter

From the model, the optimum values are:

Geometry (slice or cube) = 100.9717

Lactic acid concentration = 0.0339 M

Sucrose concentration = 47.2674 ˚Brix

Temperature = 47.2369 ˚C

The result of the analysis of a set of experimental data can be displayed in table form known as the *analysis of variance table*. The analysis of variance table displaying the total, regression (SS), and residual sums of squares (MS) as shown in Table 18. The entries in the table represent sources that contribute to the total variation in the data values. The total variation in the data values is called the “total sum of squares”. Total sum of square is the sum of two quantities; the sum of square due to the regression (SS) and sum of squares of the residuals (MS). The quantity of total sum of square has associated with it N-1 degree of freedom (df) with N is the total number of observations collected.

| Factor | SS | df | MS | F | p |
|---|---|---|---|---|---|
| 4 factors, 2 Blocks, 22 Runs; MS Residual=99.92472 DV: WR_% | | | | | |
| Blocks | 38.305 | 1 | 38.3049 | .383337 | .558583 |
| (1)GEOMETRY(L) | 19.727 | 1 | 19.7269 | .197417 | .672391 |
| GEOMETRY(Q) | 364.298 | 1 | 364.2977 | 3.645721 | .104798 |
| (2)LAC.CON (L) | 377.195 | 1 | 377.1949 | 3.774790 | .100041 |
| LAC.CON (Q) | 86.327 | 1 | 86.3268 | .863918 | .388510 |
| (3)SUC.CON (L) | 175.224 | 1 | 175.2242 | 1.753562 | .233637 |
| SUC.CON (Q) | 123.529 | 1 | 123.5287 | 1.236218 | .308756 |
| (4)TEMP_D (L) | 70.311 | 1 | 70.3108 | .703637 | .433705 |
| TEMP_D (Q) | 152.827 | 1 | 152.8267 | 1.529418 | .262409 |
| 1L by 2L | 359.650 | 1 | 359.6500 | 3.599209 | .106589 |
| 1L by 3L | 111.369 | 1 | 111.3690 | 1.114529 | .331743 |
| 1L by 4L | 272.579 | 1 | 272.5792 | 2.727845 | .149702 |
| 2L by 3L | 1.081 | 1 | 1.0812 | .010820 | .920543 |
| 2L by 4L | 55.895 | 1 | 55.8946 | .559367 | .482789 |
| 3L by 4L | 272.057 | 1 | 272.0571 | 2.722621 | .150028 |
| Error | 599.548 | 6 | 99.9247 | | |
| Total SS | 7407.931 | 21 | | | |

Table 18 : Regression Analysis for Weight Reduction Values, Quadratic Response surface Model Fitting (ANOVA)

In addition to computing the sums of squares, mean squares, and F-ratios the Statistica's program also computes a P-value, which is area under the F-Distribution density to the right of the calculated F-ratios.

$$F = \frac{\text{MS Due to Regression}}{\text{MS Residual}}$$
$$= \frac{38.3049}{99.9247}$$
$$= 0.3833$$

P-values calculated by the program will be comparing with the F-ratios values to determine which factors and interactions have significance effects. When the P-value for a particular factor is smaller than F-values, the factors was significant.

The Pareto chart from Figure 1 shows the ANOVA standardized effect estimates sorted by their absolute size to indicate the minimum magnitude of statistically significant effects.

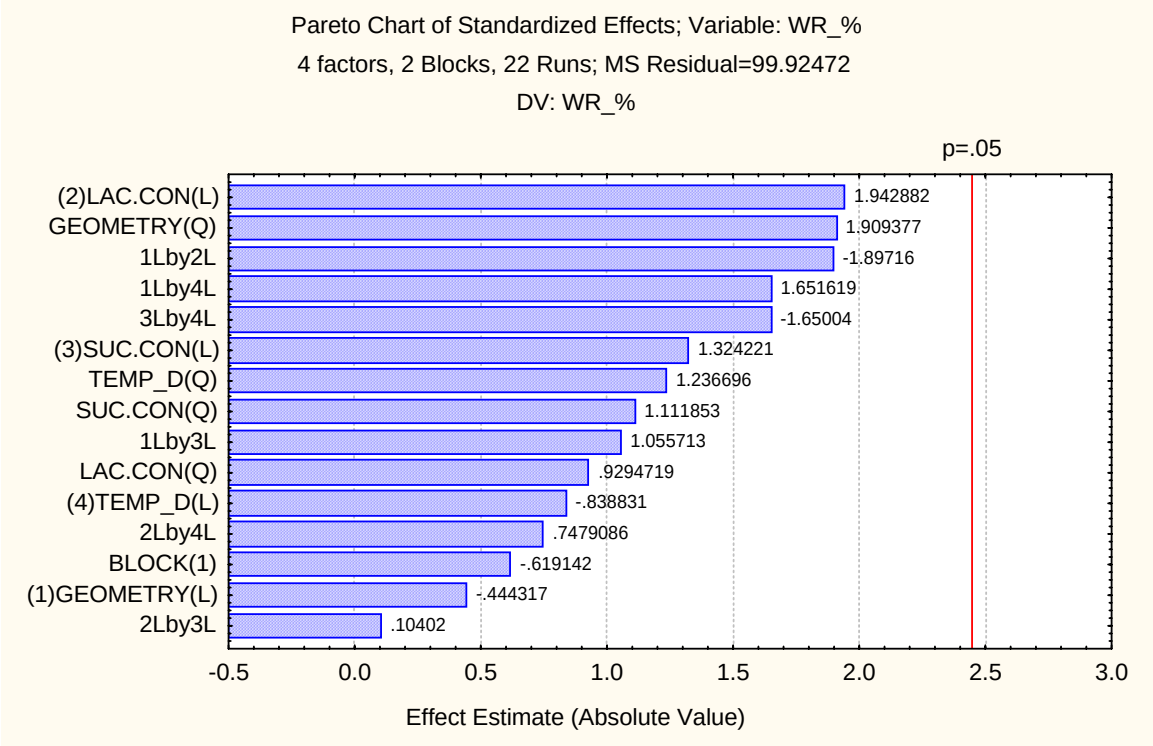



Figure 4.18: Pareto Chart of Effect of Variables for Experimental Design of Weight Reduction.

The Pareto chart shows the effect estimate of the most important factor. In this case, the most important factor is lactic acid concentration, geometry of samples, sucrose concentration and followed by temperature respectively. From this result, we can decide that the lactic acid concentration is the most important factor and help to increase weight reduction of samples. However, from the Pareto chart above, the small differential value between lactic acid concentrations to the geometry of the samples makes the geometry of the samples also as the main important factor to increase percentage weight reduction of samples.

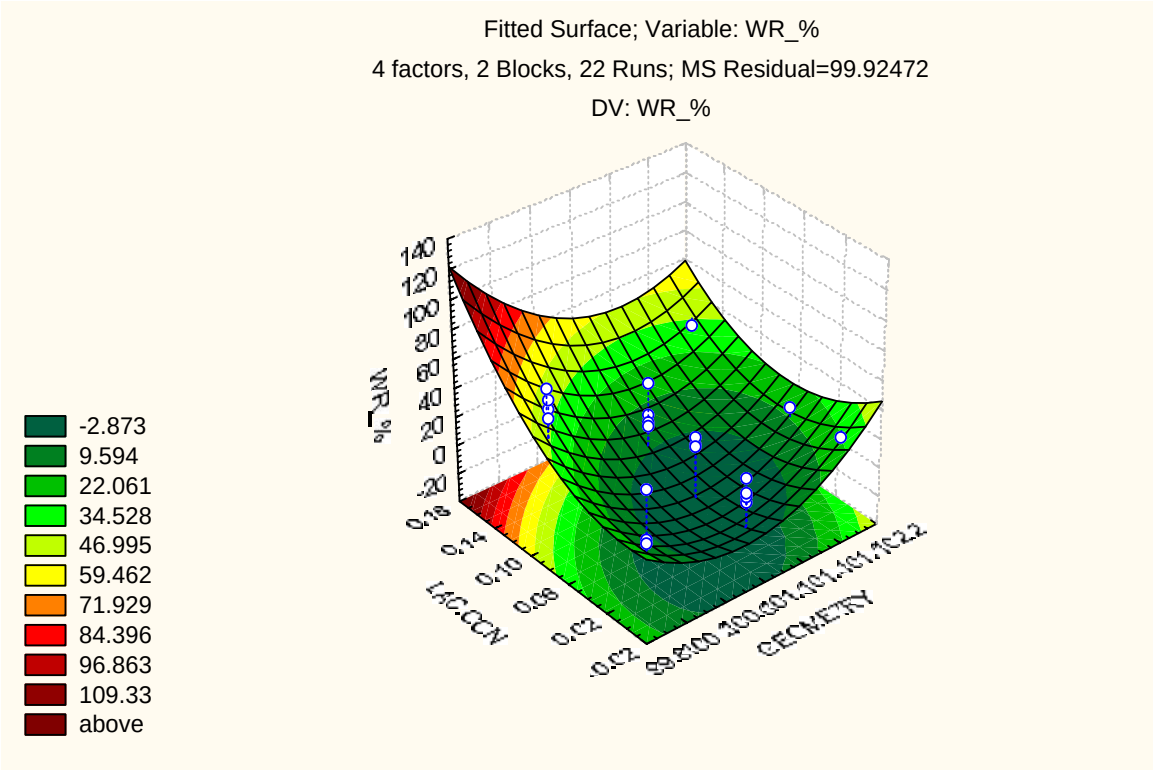



Figure 4.19: Contour Surface Plot of Weight Reduction Value as a Function of Lactic Acid Concentration and Geometry.

$$z = 271568.01789165 - 5334.2873683485 * x + 26.212109756689 * x\text{^}2 + 18788.563171948 * y + 3217.3922055335 * y\text{^}2 - 189.64440580902 * x * y + .52765765344068 * 47.2674 * x + .47432932927146 * 47.2369 * x + .51990412355499 * 47.2674 * y + 2.4920902441591 * 47.2369 * y - 4988.2448$$

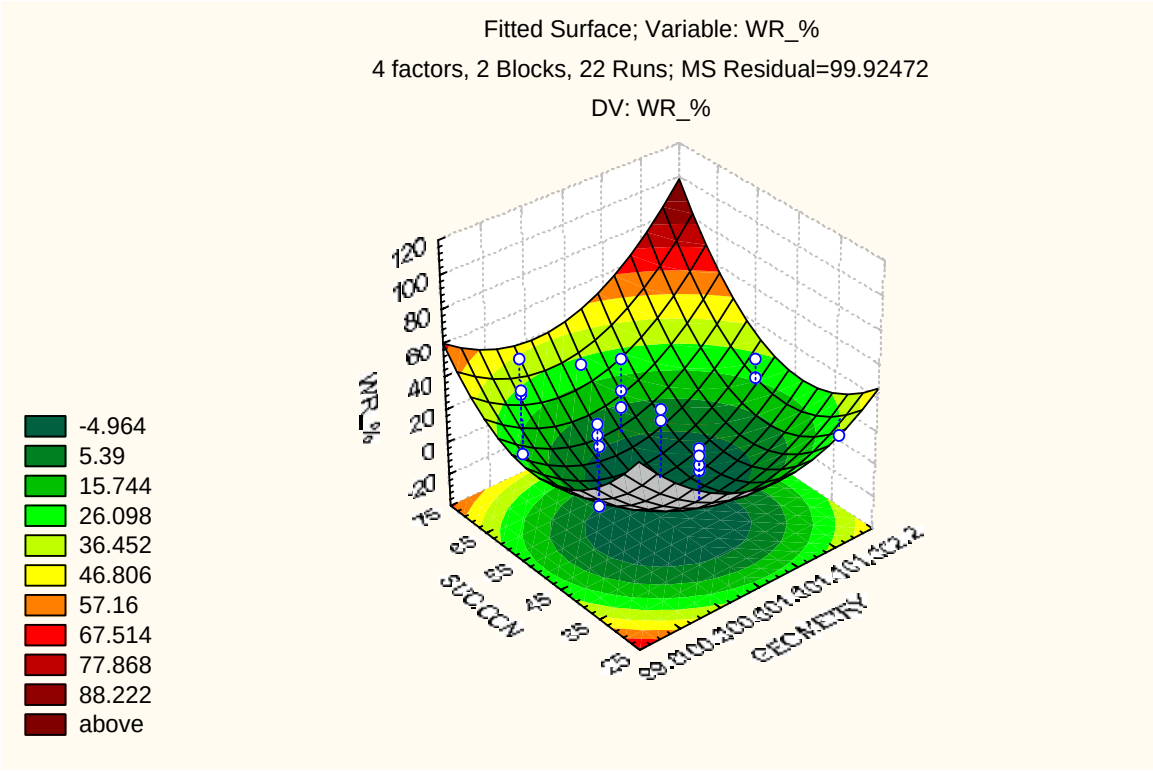



Figure 4.20: Contour Surface Plot of Weight Reduction Value as a Function of Sucrose Concentration and Geometry.

$$z = 271568.01789165 - 5334.2873683485 * x + 26.212109756689 * x\text{^}2 - 58.935448146973 * y + .073390161829587 * y\text{^}2 - 189.64440580902 * .0339 * x + .52765765344068 * x * y + .47432932927146 * 47.2369 * x + .51990412355499 * .0339 * y - .027490257732913 * 47.2369 * y - 1660.4885$$

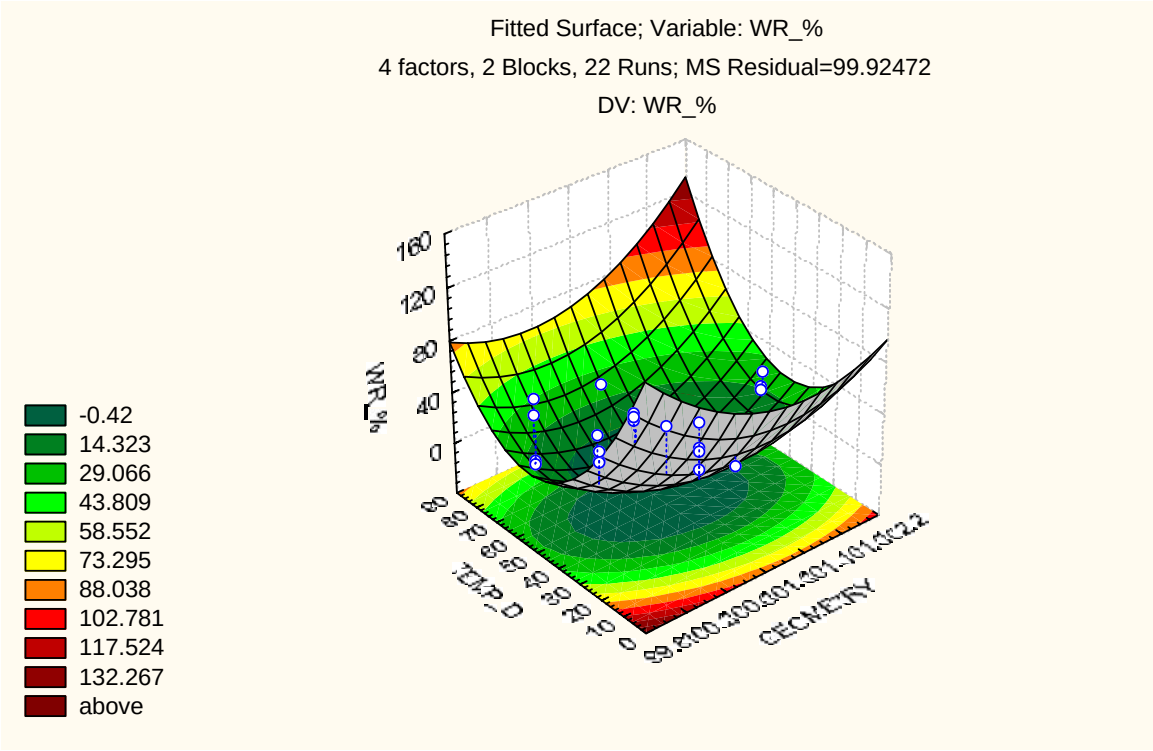



Figure 4.21: Contour Surface Plot of Weight Reduction Value as a Function of Temperature and Geometry.

$$z = 271568.01789165 - 5334.2873683485 * x + 26.212109756689 * x\text{^}2 - 50.919003902798 * y + .044882298129873 * y\text{^}2 - 189.64440580902 * .0339 * x + .52765765344068 * 47.2674 * x + .47432932927146 * x * y + 2.4920902441591 * .0339 * y - .027490257732913 * 47.2674 * y - 1980.2938$$

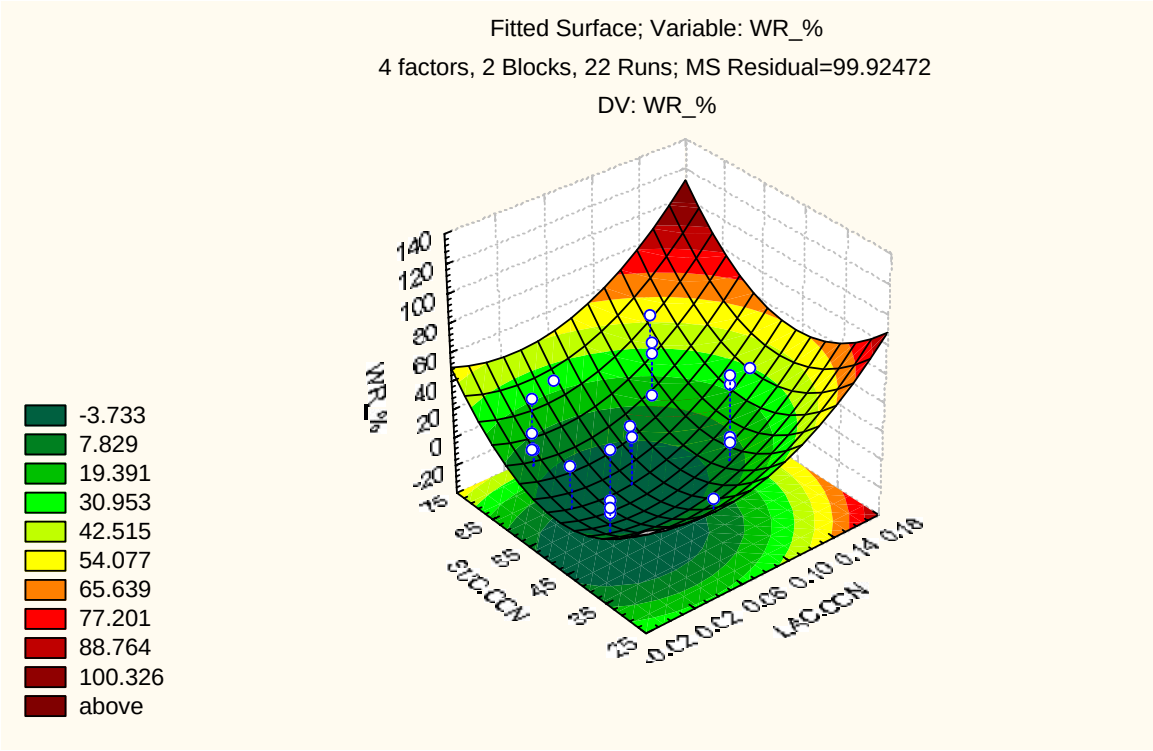



Figure 4.22: Contour Surface Plot of Weight Reduction Value as a Function of Sucrose and Lactic Acid Concentration.

$$z = 271568.01789165 + 18788.563171948 * x + 3217.3922055335 * x\text{^}2$$
$$- 58.935448146973 * y + .073390161829587 * y\text{^}2$$
$$- 189.64440580902 * 100.9717 * x + .52765765344068 * 100.9717 * y$$
$$+ .51990412355499 * x * y + 2.4920902441591 * 47.2369 * x$$
$$- .027490257732913 * 47.2369 * y - 271414.91$$

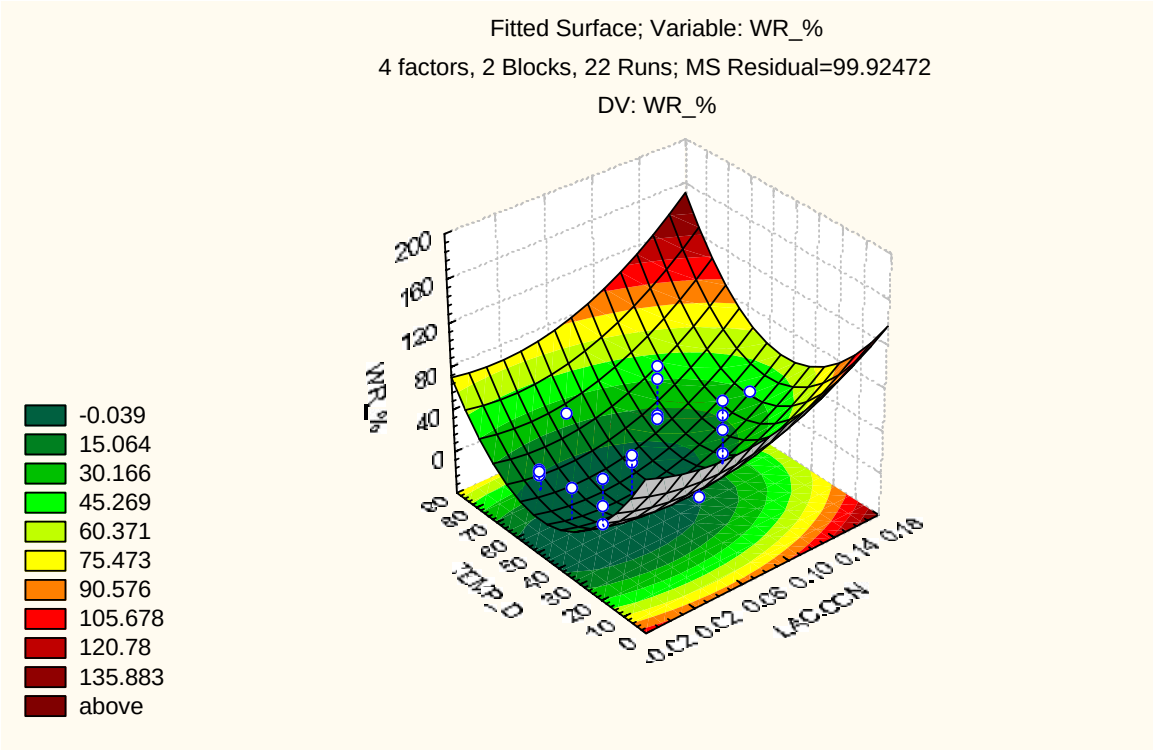



Figure 4.23: Contour Surface Plot of Weight Reduction Value as a Function of Temperature and Lactic Acid Concentration.

$$z = 271568.01789165 + 18788.563171948 * x + 3217.3922055335 * x\text{^}2$$
$$- 50.919003902798 * y + .044882298129873 * y\text{^}2$$
$$- 189.64440580902 * 100.9717 * x + .47432932927146 * 100.9717 * y$$
$$+ .51990412355499 * 47.2674 * x + 2.4920902441591 * x * y$$
$$- .027490257732913 * 47.2674 * y - 271475.58$$

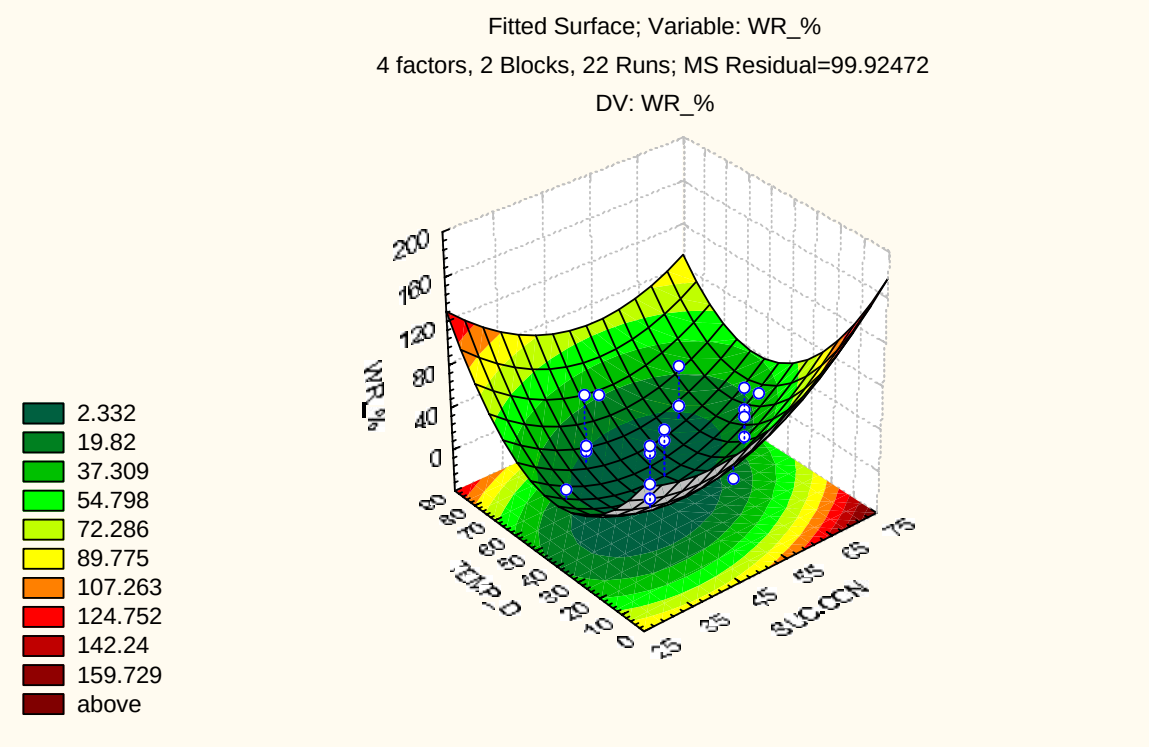



Figure 4.24: Contour Surface Plot of Weight Reduction Value as a Function of Temperature and Sucrose Concentration.

$$z = 271568.01789165 - 58.935448146973 * x + .073390161829587 * x\text{^}2 - 50.919003902798 * y + .044882298129873 * y\text{^}2 + .52765765344068 * 100.9717 * x + .47432932927146 * 100.9717 * y + .51990412355499 * .0339 * x + 2.4920902441591 * .0339 * y - .027490257732913 * x * y - 271380.67$$

# CHAPTER IV

# CONCLUSION

## 5.1 Comparison of different drying methods

The comparison of the product quality among three drying methods; microwave drying, tray drying and osmotic dehydration process, cannot be made. This is due to the different sample volume for each method. Nevertheless, the conclusion of the effect of process variable on the product quality for each method is stated in the next section.

## 5.2 Microwave drying of papaya fruit drinks

From the study, it can be concluded that microwave power intensity influenced the drying characteristics of papaya fruit. As microwave power increased, the drying rate increased. As to achieve moisture content to nearly zero during microwave drying of papaya, increase in power intensity results in shorter drying time. The processing time for microwave power 380 W and 750 W were slightly the same. However for microwave power 110 W, the time required to remove the moisture until low moisture content in papaya cubes is 20 minutes, compared to 4 minutes for 380 W and 750 W.

Drying rates were higher during higher moisture content and decreased with decreasing moisture content. The drying rate increased with increasing of power intensity at the same moisture content. The comparison made for power intensity showed that at lower microwave power, the drying rate was low and increased during higher power levels. The results indicated that mass transfer is rapid during larger microwave power heating because more heat was generated within the samples, creating a larger vapor pressure differential between the centre and the surface of products (Lin et al., 1998). Although papayas have high moisture content, an expected constant rate period was not observed in this study. It is obvious that the entire drying process for the samples occurred in the range of falling rate period.

## 5.3 Tray drying of papaya fruit drinks

From the obtained result, it has been approved that temperature was the most important factor affected the drying rate and quality of fresh papaya for each geometry of slice and cube. Increase of air temperature and air velocity caused reduction of moisture content. However, geometry cut was the most significant

factor played as a controlling effect on moisture content, in which larger surface exposure helps temperature to take action strongly. Papaya slices suffered higher water loss than cubes with regression level ($R^2$) 0.932.

The best quality of papaya fruit drinks is determined by the minimum moisture content and the maximum enzyme concentration retained. The summary result obtained from statistical experimental design, showing that the minimum moisture content is 0.8986 kg water/kg dry weight and the maximum enzyme activity is 0.0042 U/mg. The optimal condition of moisture content corresponds at coordinate point (1, 1, 40) of geometry, air velocity and temperature respectively while optimal condition for enzyme activity was significant at coordinate point (1,1,60).

## 5.4 Osmotic dehydration of papaya fruit drinks

The results obtained from all analysis were analyzed statistically using Response Surface Methodology. The data were analyzed using regression procedure to estimate the optimum parameters for each response variable.

The critical values for the parameters of enzyme activity response are; geometry (101.33), lactic acid concentration (0.17M), sucrose concentration (53.67°B) and temperature (37.48°C). The optimum value for enzyme activity occurred at 0.003527 U/mg. The interaction between temperature and geometry affected the quality of the product in term of enzyme activity. However, there is no significant effect of temperature and geometry to the moisture content.

The critical values for water loss variable are; geometry (100.63), lactic acid concentration (0.0000M), sucrose concentration (47.4348°B) and temperature (48.6465°C). Geometry and sucrose concentration show the most effects on the water loss of the product. The value of water loss was determined using the fitted model. From the surface contour graph, it is concluded that higher sucrose concentration with higher value geometry gives higher water loss. This is because large size of sample geometry has larger amount of moisture content.

Osmotic dehydration technique is one of the best methods for pre-treatment process before finish drying method such as conventional drying or microwave drying.

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# EFFECT OF DRYING PARAMETERS AND GEOMETRY ON PAPAYA QUALITY

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Due to the importance of minimizing thermal stresses over drying and maintenance of relevant compounds, selection of proper drying condition is necessary to maintain the quality of the processed fruit. The aim of this project is to study the effect of various drying parameters *i.e.* temperature, air velocity and geometry cut on the quality of papaya based on moisture content. Slices (0.5 x 1.5 x 1.5 cm) and cubes (1.0 cm) of papaya were treated in tray drier (Armfield UOP8) at different levels of temperature (40, 50 and 60 ºC) and air velocity (0.5, 1.0 and 1.5 m/s). Temperature was found to be significantly influencing the drying performance for both slices and cubes. However, geometry was the most significant factor played as a controlling effect on moisture content, in which larger surface exposure helps temperature to take action strongly. Slices suffered higher water loss than cubes with regression level ($R^2$) 0.932.

Keywords: tray drying; papaya; moisture content; geometry; response surface methodology

USM 4th Food Science and Technology Seminar
23 July 2005, Universiti Sains Malaysia

# Effect of Osmotic Dehydration Parameters on Papain Enzyme Activity of Papaya

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Due to the increasing demands of fruit drink mixes, papaya fruit tea is proposed for commercialization as a nutritious tea drink by maintaining the quality of the processed fruit. The aim of this project is to study the effect of various processing parameters on quality of the preserved papaya based on papain enzyme activity. Slices (1.5 x 1.5 x 0.5 cm) and cubes (1.0 cm) of papaya were treated in solution of sucrose (45, 55 and 65 ºBrix) and lactic acid (0, 0.005 and 0.10 M) under specified temperature (30, 40 and 60 ºC). Osmotic dehydration process was carried out for 24 hours. Analysis of papain enzyme activity was then carried out. Analysis of variance (ANOVA) using Statistica 5.0 was performed to determine the lack of fit and the significance of the product effect of the independent variables on the quality attributes. Preservation of fruit by osmotic dehydration has been proved to increase product quality retention. A unique processing technique of papaya fruit tea has been established by optimization of the dehydration process.

*Keywords*: papaya, osmotic dehydration, papain, enzyme activity, response surface

# Effect of Microwave Power Intensity on Drying Characteristic of *Carica papaya* L.

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Microwave drying is of increased interest among food researchers. The microwave power plays an important part to ensure that the product quality is improved. The aim of this project is to study the effect of power intensities during microwave dehydration on drying characteristics of *Carica papaya* L. Papaya cubes of 2 cm were treated in microwave oven at different power levels (110W, 380W and 750W) until the moisture content reached nearly zero. The effect of changing the microwave power intensity on the drying characteristics of papaya cubes is studied. The drying rate increased with increasing of power intensity at the same moisture content. Higher microwave power level results in shorter drying time.

Keywords: papaya, microwave drying, drying characteristics, moisture content

# Effect of Osmotic Dehydration Parameters on Papain Enzyme Activity of *Carica papaya* L.

**Nurul Asyikin Zaki*, Rosmaria Abu Darim, Liza Md Salleh, Ida Idayu Muhamad**

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## Abstract

Due to the increasing demands of fruit drink mixes, papaya fruit tea is proposed for commercialization as a nutritious tea drink by maintaining the quality of the processed fruit. The aim of this project is to study the effect of osmotic dehydration parameters on quality of the preserved papaya (*Carica papaya* L.) based on papain enzyme activity. Slices (1.5 x 1.5 x 0.5 cm) and cubes (1.0 $cm^3$) of papaya were treated in solution of sucrose (45, 55 and 65 ºBrix) and lactic acid (0, 0.05 and 0.10 M) under specified temperature (30, 40 and 60 ºC). Osmotic dehydration process was carried out for 24 hours. Analysis of enzyme reaction was then carried out. Analysis of variance (ANOVA) using Statistica 5.0 was performed to determine the lack of fit and the significance of the product effect of the independent variables on the quality attributes. Preservation of papaya by osmotic dehydration has been proved to increase quality retention.

*Keywords*: papaya, osmotic dehydration, papain, enzyme activity, response surface

## Background

Osmotic dehydration is a pre-treatment method used for attaining better quality fruits. It is a useful technique that involves product immersion in a hypertonic aqueous solution leading to a loss of water through the cell membranes of the product and subsequent flow along the inter-cellular space before diffusivity in the solution (Sereno *et al.*, 2001). It is an efficient form of moisture removal from solid food to inhibit the growths of microorganisms, besides preventing a large part of biochemical reactions, causing no change of phase of the water (Bolin, 1983). An important factor in improving preserved fruits quality is the moisture content. Moisture content determines the water loss in dried products, in which lower moisture content provides higher quality in products preservation. Graziella *et al.* (2004) reported on the effect of geometry of fruit cut on water loss, weight loss and solid gain of osmo-dehydrated papaya. Another aspect to be considered is the retention of nutrients and biologically active ingredients such as enzymes. The stability of papain, an enzyme found in papaya is also influenced by drying process. Therefore, the aim of this project is to study the effect of osmotic dehydration parameters on papain enzyme activity of papaya.

## Materials & Methods

**PREPARATION OF PAPAYA FRUIT**
Slices ( 0.1 x 1.5 x 1.5 cm)
Cubes ( 1.0 $cm^3$)

⇩

**OSMOTIC DEHYDRATION PROCESS**
Temperature (30, 40 and 60 ˚C)
Sucrose Concentration (45, 55 and 65 Brix)
Lactic Acid (0, 0.05 and 0.10 M)
Agitation 80 rpm

⇩

**PAPAIN ENZYME ANALYSIS**
Protein Assay

$$U / mg = \frac{A \times C \times 10}{W}$$

⇩

**RESPONSE SURFACE METHODOLOGY**
ANOVA Statistica 5.0

## Results & Discussion

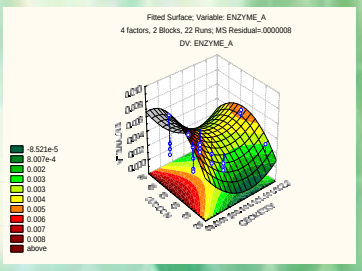


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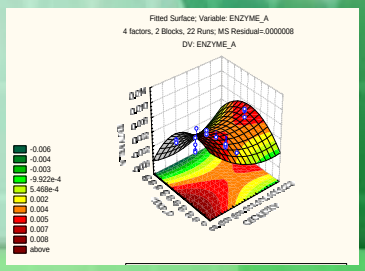
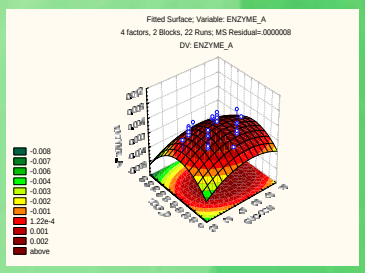
Fig. 1. Response surface of enzyme activity with sucrose concentration and geometry, and fitted model of enzyme activity value as function of the parameters



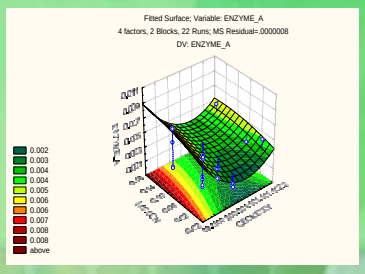

Z = 23.116776632396 - 0.45476785054866X + 0.0022346296357955$X^2$ - 0.0072011507232675Y - 0.0000032483884393514$Y^2$ - 0.002161235099074* 0.17X - 0.000101144164406 40681* 53.6658X + 0.0000745995685168 24XY - 0.000468102678727 45* 0.17Y - 0.0000006544537907 7491* 53.6658Y + 0.111390137

Fig. 2. Response surface of enzyme activity with temperature and geometry, and fitted model of enzyme activity value as function of the parameters




Z = 23.116776632396 + 0.0015939358894136X – 0.0000054774839779093$X^2$ – 0.0072011507232675Y – 0.0000032483884393514$Y^2$ – 0.000101144164406 40681* 101.3327X + 0.0000745995685168 24* 101.3327Y + 0.0002555355689 75708* 0.17X – 0.000468102678727 45* 0.17Y – 0.0000006544537907 7491XY - 23.134905

Fig. 3. Response surface of enzyme activity with temperature and sucrose concentration, and fitted model of enzyme activity value as function of the parameters




Z = 23.116776632396 - 0.45476785054866X + 0.0022346296357955X2 + 0.23945552580742Y - 0.048842617767441Y2 - 0.002161235099074XY - 0.000101144164406 40681* 53.6658X + 0.0000745995685168 24* 37.481X + 0.0002553556897 5708* 53.6658Y - 0.0004681026787 2745* 37.481Y - 0.20602156

Fig. 4. Response surface of enzyme activity with lactic acid concentration and geometry, and fitted model of enzyme activity value as function of the parameters

## Conclusion

Papaya slices suffered higher enzyme degradation compared to cubes of papaya. Increase in osmotic solution concentration and process temperature results in higher osmotic dehydration rate. Model obtained for papain enzyme activity response through response surface methodology was significant ($R^2$ = 0.94) and predictive, as shown:

$$Y = 23.11678 - 0.45477\,X_1 + 0.00223\,X_1^2 + 0.23946\,X_2 - 0.04884\,X_2^2 + 0.00159\,X_3 - 0.00001\,X_3^2 - 0.0072\,X_4 - 0.00216\,X_1X_2 - 0.00001\,X_1X_3 + 0.00007\,X_1X_4 + 0.00026\,X_2X_3 - 0.00047\,X_2X_4$$

## References

Bolin, H.R., Huxsoll, C.C., Jackson, R. and Ng, K.C. (1983) Effect of osmotic agents and concentration on fruit quality. Journal of Food Science, 48 (1): 202-205.

Graziella, C.A., Patricia, M.A., Denise, G.A., El-Aouar, A.A. and Fernanda, M.E.X. (2004). Osmotic dehydration of papaya (*Carica papaya* L.): Influence of process variables. Proceedings of the 14th International Drying Symposium. Sao Paulo, Brazil.

Sereno, A.M., Moreira, R., and Martinez, E. (2001). Mass transfer coefficients during osmotic dehydration of apple in single and combined aqueous solution of sugar and salt. Journal of Food Engineering, 47: 43-49

## Acknowledgement

The financial support from Research Management Centre, UTM Skudai (vot 75146) and Bioprocess Engineering Department, FKKKSA were gratefully acknowledged.

# Effect of Microwave Power Intensity on Drying Characteristics of *Carica papaya* L.

**Nurul Asyikin Zaki*, Ida Idayu Muhamad, Liza Md. Salleh**

Bioprocess Engineering Department, Faculty of Chemical Engineering and Natural Resources, Universiti Teknologi Malaysia, 81310 Skudai, Johor.

## Abstract

Microwave drying is of increased interest among food researchers. The microwave power plays an important part to ensure that the product quality is improved. The aim of this project is to study the effect of power intensities during microwave dehydration on drying characteristics of *Carica papaya* L. Papaya cubes of 2 $cm^3$ were treated in microwave oven at different power levels (110W, 380W and 750W) until the moisture content reached 0.1 kg/kg d.b. The effect of changing the microwave power intensity on the drying characteristics of papaya cubes is studied. The drying rate increased remarkably with the increase of power intensity at the same moisture content. Higher microwave power level results in shorter drying time.

Keywords: papaya, microwave drying, drying characteristics, moisture content

## Background

Papaya (*Carica papaya* L.) has been regarded as one of the most valuable tropical fruits that contains beta carotene, protein, carbohydrate, vitamins and minerals. Thus processing and preservation of papaya is important to improve the product quality and retain its nutritional value. Selection of proper drying technique and conditions is necessary to optimize the drying performance while retain the quality of the dehydrated product. In recent years, microwave drying has offered an alternative way to improve the quality of the dehydrated products.

Major advantages of microwave drying of foods are higher drying rate, energy saving and uniform temperature distribution giving a better product quality (Wang and Sheng, 2005). The microwave energy penetrates directly into the material, causes volumetric heating from the inside out of the material and provides fast and uniform heating throughout the entire product. The quick energy absorption by water molecules causes rapid evaporation of water, resulting in higher drying rate of the food and creating an outward flux of rapidly escaping vapor. Because the removal of moisture is accelerated, the heat transfer to the solid is slowed down significantly due to the absence of convection (Wang and Xi, 2005). The increased drying rate and lower heat transfer provides energy saving of microwave drying. The aim of this project is to study the effect of microwave power intensities on drying characteristics of *Carica papaya* L.

## Materials & Methods

**PREPARATION OF PAPAYA FRUIT**
**Hand-peeled and Cut**
**Cubes ( 2.0 $cm^3$)**

↓

**MICROWAVE DRYING PROCESS**
**(Wang & Sheng, 2005)**
**Power Intensity (110W, 380W, 750W)**

↓

**MOISTURE CONTENT DETERMINATION**
**Oven Method (Funebo, 2000)**

$$MoistureContent = \frac{Wetweight - dryweight}{dryweight}$$

## Results & Discussion

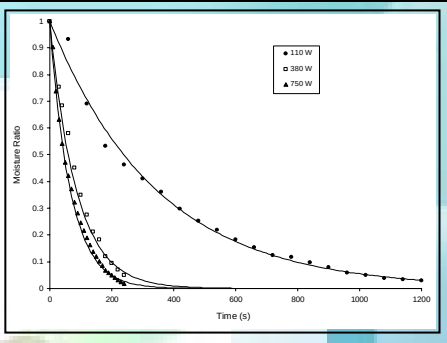



Fig. 1. Moisture ratio versus time at different microwave power intensities

Figure 1 shows the moisture ratio versus time during microwave drying of papaya cubes at different power intensities. As the microwave power intensity increased, the time required to achieve low moisture content *i.e.* 0.1 kg/kg d.b. decreased. Four and five minutes processing times were required for microwave power 380W and 750W respectively. However for 110W, longer time was required *i.e.* 14 minutes.

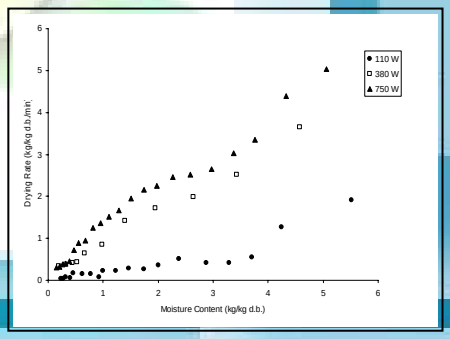



Fig. 2. Drying rate versus moisture content at different microwave power intensities

The effect of changing the microwave power intensity on the drying characteristics of papaya cubes is shown in Figure 2. Drying rates were higher at higher moisture content and decreased with the reduce of moisture content. The drying rate increased remarkably with power intensity at the same moisture content. The comparison between different power intensities showed that using lower microwave power, the drying process was slower. When higher power levels were used, the drying process was more rapid as illustrated by the gradients. These indicated that using large microwave power, more heat was generated within the samples causing rapid mass transfer creating a large vapor pressure differential between the centre and the surface of products (Lin et al., 1998). Although papayas have high moisture content, an expected constant rate period was not observed in this study. It is obvious that the entire drying process for the samples occurred in the range of falling rate period.

## Conclusion

Microwave power intensity influences the drying characteristics of papaya fruit. The drying rate increased remarkably with the increase of power intensity at the same moisture content. Higher microwave power level during microwave drying of papaya cubes results in shorter drying time.

## References

Funebo, T., Ahrné, L., Kidman, S., Langton, M. and Skjöldebrand, C. (2000). Microwave heat treatment of apple before air dehydration – effects on physical properties and microstructure. *Journal of Food Engineering*, *46*, 173-182.

Maskan, M. (2000). Microwave/air and microwave finish drying of banana. *Journal of Food Engineering, 44*, 71-78.

Wang, J. & Sheng, K. (2005). Far-infrared and microwave drying of peach. *Food Science and Technology, In Press, Corrected Proof.*

Wang, J. & Xi, Y.S. (2005). Drying characteristics and drying quality of carrot using a two-stage microwave process. *Journal of Food Engineering, 68*, 505-511.

## Acknowledgement

The financial support from Research Management Centre, UTM Skudai (vot 75146) and Bioprocess Engineering Department, FKKKSA were gratefully acknowledged.

RESEARCH MANGEMENT CENTRE
PROGRESS REPORT FOR FUNDAMENTAL RESEARCH GRANT

FOR OFFICIAL USE ONLY

Date Received
i) JKKP : .....
ii) RMC : .....
No. of Report : .....

FOR EVERY 6 MONTH AFTER PROJECT APPROVED ..... (CIRCLE ONE)
(Please TYPE and submit only ONE (1) copy. Please be brief with MAXIMUM of 4 pages).

NAME OF PROJECT LEADER : DR. IDA IDAYU BINTI MUHAMAD

UTM I/D NO : 7307

VOTE NO : 75146

i) SEO CODE

| S | | | | | | |
|---|---|---|---|---|---|---|

ii) FOR CODE

| F | | | | | | |
|---|---|---|---|---|---|---|

SEO & FOR CODE ( Please check with the recent MASTIC handbook (ed. 1999) for the updated codes. Please ignore them if the recent codes were similar to the ones in your project proposal (UTM/RMC/F/0001(1999) or if you have noted in your previous progress report.

1. (a) PROJECT TITLE :
EFFECT OF PROCESSING PARAMETERS ON THE DRYING OF PAPAYA FRUIT TEA

(b) PROJECT OBJECTIVE(S) :
To study the effect of various processing parameters on quality of papaya fruit tea

2. NEW RESEARCHERS :

| | NAME | POSITION (CHOOSE ONE CODE)* | UTM ID |
|---|---|---|---|
| (i) | ..... | ..... | ..... |
| (ii) | ..... | ..... | ..... |

RESEARCHERS WHO LEFT THE PROJECT :

| | NAME : | POSITION (CHOOSE ONE CODE)* | UTM ID |
|---|---|---|---|
| (i) | ..... | ..... | ..... |
| (ii) | ..... | ..... | ..... |

*** Position's code : Researcher (1), Research Assistant (2), Research Officer (3), Fellowship (4), MSc. (5), Ph. D Student (6)**

3. APPROVED PERIOD : STARTING DATE: 01/09/2004 EXPECTED COMPLETION DATE: _____

4. PROBLEM FACED (Pleased tick)

| | YES | NO | | YES | NO |
|---|---|---|---|---|---|
| FUNDING | ( ) | ( / ) | MANPOWER | ( ) | ( / ) |
| EXECUTION | ( ) | ( / ) | EQUIPMENT | ( ) | ( / ) |
| TIME | ( ) | ( / ) | LACK OF INTEREST | ( ) | ( / ) |
| SPACE | ( ) | ( / ) | | | |

OTHER *(briefly detail-out)*

.....

.....

HAVE YOU HIGHLIGHTED THE ABOVE PROBLEMS TO RMC/FACULTY?

.....

5. LIST OF EQUIPMENT BOUGHT USING THIS VOT
Vacuum pump, pH meter, Blender, Hotplate Stirrer

06. OPERATION PLAN :

| No. | PROJECT ACTIVITIES | MONTH | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | Literature study | | | | | | | | | | | | |
| 2 | Fruit selection and brix index determination | | | | | | | | | | | | |
| 3 | Equipment purchasing and installation | | | | | | | | | | | | |
| 4 | Experiment and data analysis | | | | | | | | | | | | |
| 5 | Evaluation studies | | | | | | | | | | | | |
| 6 | Process optimization of product | | | | | | | | | | | | |
| 7 | Technology transfer activities | | | | | | | | | | | | |

● Milestone completed

◌ Milestone not completed

7. a) SUMMARY OF RESEARCH PROGRESS TILL THE DATE OF THIS PROJECT

The objective of this research is to study the effect of various processing parameters on the quality of papaya fruit tea. Studies that have been carried out:

i) Drying of papaya by tray dryer, determination of moisture content and papain enzyme activity of dried product, evaluation of drying parameters effect on the product quality, and process optimization by statistical analysis.

ii) Preservation of papaya by osmotic dehydration, determination of moisture content and papain enzyme activity of preserved product, evaluation of processing parameters effect on the product quality, and process optimization by statistical analysis.

iii) Drying of papaya by microwave oven, determination of moisture content and vitamin C retention of dried product, and study of effect of drying parameters on the quality of dried product.

b) LIST OF PAPERS PRESENTED/PUBLISHED FOR THE LAST SIX MONTHS (INCLUDE TITLE NAMES, DATE, PLACE, AND ORGANIZER/PUBLISHER) (Please enclosed a copy of each paper)

1. Effect of Microwave Power Intensity on Drying Characteristics of *Carica papaya* L.
   22 November 2005, Genting Highlands Resort
   First International Symposium on Papaya

2. Effect of Osmotic Dehydration Parameters on Papain Enzyme Activity of *Carica papaya* L.
   23 July 2005, Universiti Sains Malaysia
   USM 4th Food Science and Technology Seminar

3. Effect of Drying Parameters on Moisture Content and Papain Enzyme Activity of Dried Papaya
   23 July 2005, Universiti Sains Malaysia
   USM 4th Food Science and Technology Seminar

4. Effect of Microwave Dehydration Parameters on the Quality of Dehydrated Papaya
   26 October 2005, Universiti Teknologi Malaysia
   1st Stage Master's Degree Proposal Presentation, FKKKSA

5. Effect of Drying Parameters and Geometry Cut on Papaya Quality
   2 & 3 May 2005, Primula Beach Resort, Kuala Terengganu
   KUSTEM 4th Annual Seminar on Sustainable Science and Management

6. The Study of Effect of Various Processing Parameters on Quality Papaya Fruit Tea
   31 March 2005, Universiti Teknologi Malaysia
   Thesis Presentation, Bioprocess Engineering Department, FKKKSA

7. Effect of Processing Parameters on the Drying of Papaya Fruit Tea
   31 March 2005, Universiti Teknologi Malaysia
   Thesis Presentation, Bioprocess Engineering Department, FKKKSA

c) STATUS OF RESULTS (Please Tick)

| | YES | NO |
|---|---|---|
| COMMERCIALISEABLE | ( ) | ( ) |
| PATENTABLE | ( ) | ( ) |
| EXHIBITABLE | ( ) | ( ) |

d) FINDINGS

The research findings are:-

i) For tray drying process, papain enzyme is best retained in the following condition:
Drying temperature 60 ºC, Air velocity 1.0 m/s, Geometry Cube

ii) For tray drying process, the optimum value for moisture content variable are:
Drying temperature 40 ºC, Air velocity 0.5 m/s, Geometry Cube

iii) For osmotic dehydration process, papain enzyme is best retained in the following condition:
Lactic acid 0.17M, Sucrose 55 ºBrix, Temperature 40 ºC

iv) For osmotic dehydration process, the optimum value for moisture content variable are:
Lactic acid 0.00M, Sucrose 50 ºBrix, Temperature 50 ºC

v) For microwave drying process, moisture content and vitamin C concentration is higher in papaya cubes compared to slices.

8. FUTURE PLAN

Recommendations: Further experiments and analysis such as sensory evaluation of the papaya fruit tea coloring, taste and aroma shall be carried out. Commercialization of papaya fruit tea as nutritious healthy drinks shall be considered.

9. FINANCIAL STATUS
(1 Sept 2004 – 31 Dec 2005)

| Project Cost Components | Approved Fund Allocation | Actual Spending (RM) | Balance (RM) |
|---|---|---|---|
| * Equipment/Accessories/ Repairs | | 6 818.00 | |
| * Materials and Supply | | 5 014.35 | |
| * Travel/Transportation | | 1 804.00 | |
| * Wage/Allowance/ Other Services | | 14 988.45 | |
| Total | 48 000.00 | 28 624.80 | |

% SPENT : 100%

10. SIGNATURE OF PROJECT LEADER ..... DATE : 26 May 2006

EVALUATION (hand written)

a) JKPP FACULTY

Research status ( ) ( ) ( ) ( ) ( ) ( )
Spending ( ) ( ) ( ) ( ) ( ) ( )
Overall Status ( ) ( ) ( ) ( ) ( ) ( )
Excellent Very Good Good Satisfactorily Fair Weak

Faculty's response to problem faced by researcher

……

……

……

Comment/Suggestion

……

……

……

…….. Name :
……
(Signature and stamp of JKP chairman)

Date : ……..

b) RMC

Research status ( ) ( ) ( ) ( ) ( ) ( )
Spending ( ) ( ) ( ) ( ) ( ) ( )
Overall Status ( ) ( ) ( ) ( ) ( ) ( )
Excellent Very Good Good Satisfactorily Fair Weak

Academic standing :

……

……

……

Notes :

……

……

……

…….. Name: ……
Signature and stamp of Dean/Deputy Dean
Research and Management Centre Date : ……..

**UNIVERSITI TEKNOLOGI MALAYSIA**

**BORANG PENGESAHAN**
**LAPORAN AKHIR PENYELIDIKAN**

TAJUK PROJEK : **EFFECT OF VARIOUS PROCESSING PARAMETERS ON THE QUALITY OF PAPAYA FRUIT TEA**

Saya, **DR. IDA IDAYU BINTI MUHAMAD**

Mengaku membenarkan **Laporan Akhir Penyelidikan** ini disimpan di Perpustakaan Universiti Teknologi Malaysia dengan syarat-syarat kegunaan seperti berikut :

1. Laporan Akhir Penyelidikan ini adalah hakmilik Universiti Teknologi Malaysia.
2. Perpustakaan Universiti Teknologi Malaysia dibenarkan membuat salinan untuk tujuan rujukan sahaja.
3. Perpustakaan dibenarkan membuat penjualan salinan Laporan Akhir Penyelidikan ini bagi kategori TIDAK TERHAD.
4. * Sila tandakan ( / )

| | | |
|---|---|---|
| ☐ | SULIT | (Mengandungi maklumat yang berdarjah keselamatan atau Kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972). |
| ☐ | TERHAD | (Mengandungi maklumat TERHAD yang telah ditentukan oleh Organisasi/badan di mana penyelidikan dijalankan). |
| √ | TIDAK TERHAD | |

TANDATANGAN KETUA PENYELIDIK

Nama & Cop Ketua Penyelidik

Tarikh : _____

**CATATAN :** ***** *Jika Laporan Akhir Penyelidikan ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan ini perlu dikelaskan sebagai SULIT dan TERHAD.*

**UNIVERSITI TEKNOLOGI MALAYSIA**
**Research Management Centre**

# PRELIMINARY IP SCREENING & TECHNOLOGY ASSESSMENT FORM

*(To be completed by Project Leader submission of Final Report to RMC or whenever IP protection arrangement is required)*

1. **PROJECT TITLE IDENTIFICATION** :

EFFECT OF PROCESSING PARAMETERS ON THE DRYING OF PAPAYA FRUIT TEA

Vote No: 75146

2. **PROJECT LEADER** :

Name : DR. IDA IDAYU MUHAMAD

Address : BIOPROCESS ENGINEERING DEPT, FKKKSA, UNIVERSITI TEKNOLOGI MALAYSIA, SKUDAI.

Tel : 07-5535541 Fax : 07-5581463 e-mail : idayu@fkkksa.utm.my

3. **DIRECT OUTPUT OF PROJECT** *(Please tick where applicable)*

| Scientific Research | Applied Research | Product/Process Development |
|---|---|---|
| ☐ Algorithm | ☐ Method/Technique | ☐ Product / Component |
| ☐ Structure | ☐ Demonstration / Prototype | ☐ Process |
| ☐ Data | | ☐ Software |
| ☐ Other, please specify _____ | ☐ Other, please specify _____ | ☐ Other, please specify _____ |

4. **INTELLECTUAL PROPERTY** *(Please tick where applicable)*

- ☐ Not patentable
- ☐ Patent search required
- ☐ Patent search completed and clean
- ☐ Invention remains confidential
- ☐ No publications pending
- ☐ No prior claims to the technology
- ☐ Technology protected by patents
- ☐ Patent pending
- ☐ Monograph available
- ☐ Inventor technology champion
- ☐ Inventor team player
- ☐ Industrial partner identified

## 5. LIST OF EQUIPMENT BOUGHT USING THIS VOT

Vacuum pump
pH meter
Blender
Hotplate Stirrer

## 6. STATEMENT OF ACCOUNT

| | | |
|---|---|---|
| a) | APPROVED FUNDING | RM : ……. |
| b) | TOTAL SPENDING | RM : ……. |
| c) | BALANCE | RM : ……. |

## 7. TECHNICAL DESCRIPTION AND PERSPECTIVE

*Please tick an executive summary of the new technology product, process, etc., describing how it works. Include brief analysis that compares it with competitive technology and signals the one that it may replace. Identify potential technology user group and the strategic means for exploitation*.

a) Technology Description

Papaya fruit tea is proposed to be a healthy beverage because of its nutraceutical value with biologically active ingredients that can promote health and is consumed as nutritional supplement.

b) Market Potential

Tea is the most widely consumed beverage in the world. The total tea produced for consumption is black tea (78%), green tea (20%) and oolong tea (2%). The market of these herb and fruit based tea is increasing as these teas are claimed to have nutraceutical values as well as medicinal values. According to 2nd Industrial Master Plan 1996-2005, Malaysia's share of world trade in processed fruit is negligible at only 0.2% despite of wide variety of tropical fruit available for export. With well-planned and systematic approaches, the marketing of this fruit based tea will increase at our local market, and will possibly be accepted over the world.

c) Commercialization Strategies

For commercialization purposes, this papaya fruit tea is mainly aimed to be distributed to hotels, franchise restaurants, spas and salons, in order to promote its beneficial use and medicinal value to consumers.

## 8. RESEARCH PERFORMANCE EVALUATION

a) FACULTY RESEARCH COORDINATOR

| | | | | | | |
|---|---|---|---|---|---|---|
| Research Status | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Spending | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Overall Status | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| | Excellent | Very Good | Good | Satisfactory | Fair | Weak |

Comment/Recommendations :

_____

_____

_____

_____

_____

…… Name : ……

Signature and stamp of JKPP Chairman

Date : ……

b) RMC EVALUATION

| | | | | | | |
|---|---|---|---|---|---|---|
| Research Status | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Spending | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| Overall Status | ( ) | ( ) | ( ) | ( ) | ( ) | ( ) |
| | Excellent | Very Good | Good | Satisfactory | Fair | Weak |

Comments :-

_____

_____

_____

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_____

_____

Recommendations :

☐ Needs further research

☐ Patent application recommended

☐ Market without patent

☐ No tangible product. Report to be filed as reference

…….. Name : …….

Signature and Stamp of Dean / Deputy Dean Date : …….
Research Management Centre