UNIVERSITI PUTRA MALAYSIA

EFFECT OF PRE-TREATMENTS IN PRODUCTION OF MUSKMELON POWDER BY FOAM MAT DRYING AND AIR FRY DRYING

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ABSTRACT

Muskmelon or *Cucumis melo* is a species of melon that has been developed into many cultivated varieties. Melons are 90% water 9% carbohydrates with less than 1% of protein and fat. Therefore, shelf life of muskmelons are short when stored. In order to elongate the shelf life, dehydration are used to form muskmelon powders but the quality of product may be affected. Then, pre-treatments were used to control product's quality. The effect of pre-treatments (citric acid & blanch) with different drying methods was investigated. Citric acid pre-treatment have two parameters (0.25% & 0.5 concentration) while blanch pre-treatment also have two parameters (60°C & 70°C). Then, it is dried with foam mat drying (50% & 100% fan speed) and air fry drying (60°C & 70°C) with two parameters respectively. The pre-treatments were found to affect the color differences, bulk and tap density, flow ability and affected the drying curves. Blanch pre-treatment does retained the dried muskmelon powders colors better and produced better flow ability than citric acid pre-treatment. Citric acid pre-treatment affected the drying curves by reducing the drying time, while for blanch pre-treatment the drying time reduced not much. Foam mat drying does retained the color of samples and produced better flow ability powders than air fry drying because the powders produced by air fry drying was sticky. The drying curves of air fry drying was steeper and shorter than foam mat drying due to the high temperature used. Noted that the temperature for foam mat drying was 42°C for 50% fan speed and 34°C for 100% fan speed. The optimum condition for drying muskmelon was dried using foam mat drying 100% fan speed and pre-treated with blanch treatment 70°C.

ABSTRAK

Muskmelon atau *Cucumis melo* adalah spesies tembikai yang telah berkembang menjadi banyak jenis yang ditanam. Melon adalah 90% air, 9% karbohidrat dan kurang dari 1% protein dan lemak. Oleh itu, jangka hayat muskmelon pendek apabila disimpan. Untuk memanjangkan jangka hayat, dehidrasi digunakan untuk membentuk serbuk muskmelon tetapi kualiti produk mungkin terjejas. Kemudian, pra-rawatan digunakan untuk mengawal kualiti produk. Kesan pra-rawatan (asid sitrik & rebusan) dengan kaedah pengeringan yang berbeza telah dikaji. Pra-rawatan asid sitrik mempunyai dua parameter (kepekatan 0,25% & 0,5) sementara pra-rawatan blanch juga mempunyai dua parameter (60 °C & 70 °C). Kemudian, dikeringkan dengan 'foam mat drying' (kelajuan kipas 50% & 100%) dan 'air fry drying' (60 °C & 70 °C) masing-masing dengan dua parameter. Pra-rawatan didapati mempengaruhi perbezaan warna, ketumpatan pukal dan ketuk, keupayaan aliran dan mempengaruhi lekuk pengeringan. Pra-rawatan rebusan mengekalkan warna serbuk muskmelon lebih baik dan menghasilkan keupayaan aliran yang lebih baik daripada pra-rawatan asid sitrik. Pra-rawatan asid sitrik mempengaruhi lekukan pengeringan dengan mengurangkan masa pengeringan, sementara untuk pra-perawatan rebusan pemgurangan masa pengeringan tidak banyak. 'Foam mat drying' mengekalkan warna sampel dan menghasilkan serbuk keupayaan aliran yang lebih baik daripada 'air fry drying' kerana serbuk yang dihasilkan adalah melekit. lekukan pengeringan 'air fry drying' lebih curam dan lebih pendek kerana suhu tinggi yang digunakan. Keadaan optimum untuk pengeringan muskmelon dikeringkan menggunakan busa pengeringan 100% kelajuan kipas dan pra-rawatan dengan rawatan blanch 70°C

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CHAPTER 1

INTRODUCTION

1.1 Overview

Cucumismelo L or known as Muskmelon is from cucumber (Cucurbitaceous) family. It well grown in warm or temperate climate area. Muskmelon fruits are consumed mostly in the summer season. The fruits can be very refreshing and sweet with nice aroma is due to the adaptation to soil and climate. However, it has a short post-harvest shelf-life.

To produce powders from the fruits, drying process will be necessary in order to remove moisture and reduce water activity. Examples of drying processes are spray dry, freeze dry and foam mat drying process. These three different types of processing have pros and cons. Spray dry applied heat from the air, the problem associated in belt/tray drying method is colour change, protein denaturization and poor rehydration quality (Sangamithra, Sivakumar, Swamy & Kannan, 2015). Freeze dry is an excellent method in order to retain the quality of the products. However, the cost to use the equipment is high. Therefore, foam mat drying is chosen to be used due to allowable the dehydration of heat sensitive, high sugar content and viscous foods without change in quality.

One purpose of drying muskmelon is to preserve it; muskmelon powder has a far longer shelf life than the fresh fruits. Powdered muskmelon does not need to be refrigerated due to its low moisture content. Therefore, risk of losing quality is reduced to transport long distance markets. The muskmelon powders can be applied in food industries. Some examples of the application on industries are processing to be yogurt, ice cream, bakery products and juices.

1.2 Problem statement

The issues regarding the short shelf life of muskmelons fruits have existed many years due to long storage time. Other than that, the quality of the fruits will be affected when there are no appropriate handling methods of the fruits. From statement, it shows that the fruits are need solutions in order to maintain when stored. Therefore, to have longer shelf life powdered form of muskmelons is needed to be made. Variations in water-activity (aw) can induce undesirable changes in dehydrated products colour antioxidant composition/activity reducing shelf-life. Pre-treatments process before drying may affected the drying time, temperature and rehydration ratios. Furthermore, heating methods also will cause nutrients losses and decreasing the quality of fruits. Different type of pre-treatments and dehydration method can be beneficial or disadvantages.

1.3 Objectives

- To study the effect of citric acid and blanch pre-treatment on moisture content, color differences, bulk and tap density, flow ability and drying curve.
- To study the effect of foam mat drying and air fry drying on moisture content, color differences, bulk and tap density, flow ability and drying curve.

1.4 Scope of study

This study was carried out ay University Putra Malaysia (UPM) to produce muskmelon powder from the flesh. Activities involved in this study are drying using different methods (foam mat drying and air fry drying) and analyzing the physical properties once powder is obtained. In this study, the importance of the muskmelon also being identified for consumers. Moisture content of products before and after drying is well investigated using equipment in laboratory. In order to produce long shelf life product, low moisture content need to be achieve with minimizing nutrient losses during drying. The powders produced can be optimized and used as final products, for example juices, ice creams, cakes and bakery products.

CHAPTER 2

LITERATURE REVIEW

2.1 Musmelon (*Cucumis melo*)

2.1.1 Introduction

Muskmelon (*Cucumis melo*), also known as cantaloupe, is a member of the Cucurbitaceae family. The fruits have yellow-orange colored fruit with a network of inertwining veins at the outside, sweet, fragrant flesh is primarily grown in the tropical region. The major pigments present in muskmelon include carotene, lutein and zeaxanthin and minor pigments are cryptoxanthin, phytoene, violaxanthin, neoxanthin and zeaxanthin. The carotenoids in muskmelon have a vital role as antioxidants which can quench reactive oxygen species that would lead to various diseases in humans, such as cancer, cardiovascular diseases and macular degeneration. The most prominent health benefits include anti-clotting influence on the blood, reduction in the risk of cancer and heart disease (Sangamithra, Sivakumar, Swamy & Kannan, 2015).

Muskmelon is cultivated in all tropical and subtropical areas of the world for its nutritional and medicinal value. The fruit is commonly known as Kharbooja in Hindi. The phytoconstituents from various parts of the plant include β-carotenes, apocaretenoids, ascorbic acid, flavonoids, terpenoids, chromone derivatives, carbohydrates, amino acids, fatty acids, phospholipids, glycolipids, volatile components and various minerals. *Cucumis melo* has been shown to possess useful medicinal properties such as analgesic, anti-inflammatory, anti-oxidant, free radical scavenging, anti-platelet, anti-ulcer, anti-cancer, anti-microbial, hepato-protective, diuretic, anti-diabetic, anthelmintic and anti-fertility activity (Milind & Kulwant, 2011).

There are already some applications that use muskmelon such as:-

- Purgative.
- Dyspepsia.
- Help in maintain kidney functions.
- Reduce blood pressure and prevent cardiac dysfunction.
- Possess anti-rheumatic and anti-gout properties.
- Act as a cooling agent, cleansing agent and moisturiser for skin.
- The fruit is stomachic and demulcent.
- Kernels are prescribed for stomach ulcer.
- Fruit pulp is employed as a lotion for chronic and acute eczema.

For miscellaneous uses of muskmelons, it usually eaten as a fresh fruits, salad or as a dessert with ice cream. Furthermore, seed kernels of the muskmelons can be used as thickening, emulsifying, fat binding and flavouring agents. The seeds also can act as an alternative to soybean for milk production. Then, the flesh of the fruit can be dried, ground into powder and used for making bread, biscuits etc (Milind & Kulwant, 2011).

Muskmelons also are high in moisture content. The moisture content of the tested tropical fruits on afresh weight (FW) basis. Watermelon and muskmelon were found to have the highest moisture content (*ca.*92%) whilst papaya had the lowest (80%).

Common Name	Scientific Name	[a]Moisture (%)
Starfruit-B10	*Averrhoa carambola* L.	91.25 ± 0.14
Mango-Chokanan	*Mangifera indica* L.	88.67 ± 0.44
Papaya-Foot Long	*Carica papaya* L.	79.75 ± 0.18
Muskmelon-Sunmelon	*Cucumis melo* L.	92.38 ± 0.17
Watermelon-redmelon	*Citruluss lanatus* (Thunb.)	92.47 ± 0.12

Figure 2.1: Common and scientific names and moisture content of tropical fruits (Norshahida et al., 2011).

2.1.2 Health benefits

Cucumis melo is an anti-cancer activity. Cucurbitacins are highly oxygenated tetracyclic-triterpenes, predominantly found in the cucurbitaceae family. Cucurbitacin B is a natural anti-cancer agent isolated from the stems of *Cucumis melo*. The anti-cancer activity of cucurbitacin B in human leukemia cells has been reported (Chan et al., 2010).

Then, anti-diabetic activity. Musk melon increased the levels of thyroid hormones and insulin indicating their potential to ameliorate the diet induced alterations in serum lipids, thyroid dysfunctions and hyperglycemia/diabetes mellitus. These beneficial effects could be due to the rich content of polyphenols and ascorbic acid in the peel extracts (Parmar & Kar, 2008).

Moreover, *Cucumis* melo as anti-microbial activity and anthelmintic activity. The n-hexane and methanolic extracts of the seeds of *Cucumis melo* L. have shown good antimicrobial, and anthelmintic activity (Ibrahim 2010).

Other than that, *Cucumis* melo as an anti-ulcer activity. The methanolic extract of *Cucumis melo* seeds exhibited anti-ulcer genic activity. The mechanism of its gastro-protective activity may be attributed to reduction in vascular permeability, scavenging of free radicals and diminished lipid peroxidation along with strengthening of mucosal barrier. Presence of triterpenoids and sterols are responsible for these actions (Gill et al., 2011).

Then, anti-oxidant and free radical scavenging activity. The methanolic extract of cantaloupe has shown DPPH and hydroxyl radicals scavenging activity. This activity of cantaloupe extract is particularly due to the presence of phenolic compounds especially flavonoids. High antioxidant activity was observed in the leaf and stem extracts of cantaloupe (Ismail et al., 2010).

2.1.3 Flesh Nutritional

Muskmelon fruits have sweet flavours and contained high antioxidants content. Menon and Rao stated that the sugars got accumulated in high amount in the ripened muskmelon fruit, indicating it as a high sucrose accumulating genotype. The quantity of sugars (reducing, non-reducing and total) increases during ripening process of the muskmelon fruits. Moreover, sudden increase of the sugars occurred at ripened stage. Other than that, the antioxidant activity was found out during young age until the fruits ripened.

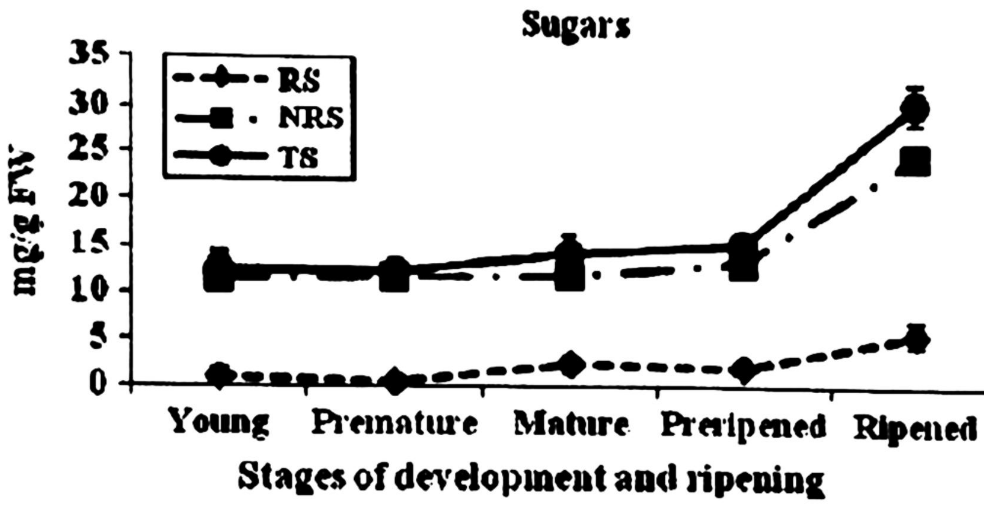


Figure 2.2: Quantitative analysis of reducing sugars, non-reducing sugars and total sugars in muskmelon at its stages of development and ripening. (Menon & Ramana Rao 2013)

Total antioxidant activity in muskmelon at development stages				
Young	**Pre-mature**	**Mature**	**Pre-ripened**	**Ripened**
0.1 mg/g	0.02 mg/g	0.04 mg/g	0.06 mg/g	0.05 mg/g

Table 2.1: Quantitative analysis of total antioxidant activity in muskmelon at its stages of development and ripening. (Menon& Ramana Rao2013)

Cantaloupe melons are an excellent source of Vitamin A, Vitamin C, Potassium and Magnesium. It has been shown to possess useful medicinal properties such as analgesic, anti-inflammatory, anti-oxidant, anti-ulcer, anti-cancer, anti-microbial, diuretic, anti-diabetic, and anti-fertility activity (Millind & Singh, 2011).

Serving size = 1 cup (236 g)		
	Amount per serving	**Percentage of daily requirement (%)**
Calories	71	
Calories from fat	0	
Total fat	0 g	0
Sodium	28 mg	1
Potassium	593 mg	15
Total carbohydrates	23 g	7
Dietary fiber	2 g	8
Sugars	19 g	
Protein	2 g	
Vitamin A		160
Vitamin C		130
Calcium		4
Iron		9

Table 2.2: Nutrient content of muskmelon flesh. (Millind & Singh, 2011).

The nutrient content of muskmelons are described as relatively low in calories, fat, and sodium. But, good sources of potassium and vitamins (A & C). In addition, muskmelon is an excellent source of pro-vitamin A or *beta*-carotene. Three compounds found in melons such as cucurbitacin-β, lithium and zinc hold promise in cancer prevention, fighting depression and in stimulating immune system (Lester, 1997).

2.1.3 Seeds Nutritional

The seeds of muskmelons have its potential benefits. Therefore, dried seeds of muskmelon (*Cucumis melo)* were analysed for different characteristics such as nutritional, phytochemical and antioxidant activity (Manika et al., 2015). The nutritional analysis shows that the seeds are a good source of energy, carbohydrates, fat, proteins and minerals such as calcium, iron, magnesium, phosphorus and potassium. Phytochemical analysis reveals that the seeds are a good source of flavonoids, phenolics, saponins, alkaloids and other secondary metabolites.

Sample	Energy (Kcal/100 g)	Total Carbohydrate %	Protein %	Fat%	Dietary Fiber%	Moisture %	Ash %
Muskmelon Seed	557.199	22.874	32.80	37.17	0.2	2.358	4.801

Table 2.3: Nutritional profile of Muskmelon. (Manika et al., 2015).

Proteins are essential for the body. From the figure above, the muskmelon has revealed their nutritional richness. It has shown the muskmelons are high in protein (32.8%), and fat content (37.167%). Carbohydrates are function as an immediate energy source. The carbohydrate content of muskmelon seeds was found to be 22.874%. Thus has high value of energy 557.199 Kcal/100g.

No.	Analyte	Sample concentration unit (ppm) in Muskmelon
1	Ca	2477
2	Cd	0.2
3	Zn	75
4	Cu	22.5
5	Fe	164
6	K	7599
7	Mg	4496
8	Mn	34.2
9	Na	74
10	Ni	1.2
11	P	9249
12	Pb	0.9
13	As	0.002
14	Hg	0.002

Table 2.4: Mineral content of Muskmelon seeds. (Manika et al., 2015).

The mineral content of muskmelon seed were analysed using ICP-OES. The seeds are high in Calcium, Magnesium, Phosphorus, Potassium and low in Iron, Sodium and Zinc. Minerals can benefits human for their health such as calcium, phosphorus and magnesium can enhance structures for bones. Sodium and magnesium maintain of normal blood pressure. Iron is a part of haemoglobin and myglobin (Saltman &Strause, 1993).

2.1.3 Peels Nutritional

The high fruit consumption produces a large quantity of waste materials, such as peels and seeds that are still rich in molecules like polyphenols, carotenoids, and other biologically active components that possess a positive influence on human health and wellness. In order to discover the benefits of the peels, composition and functional activity of melon peels were studied (Vella et al.,2019).

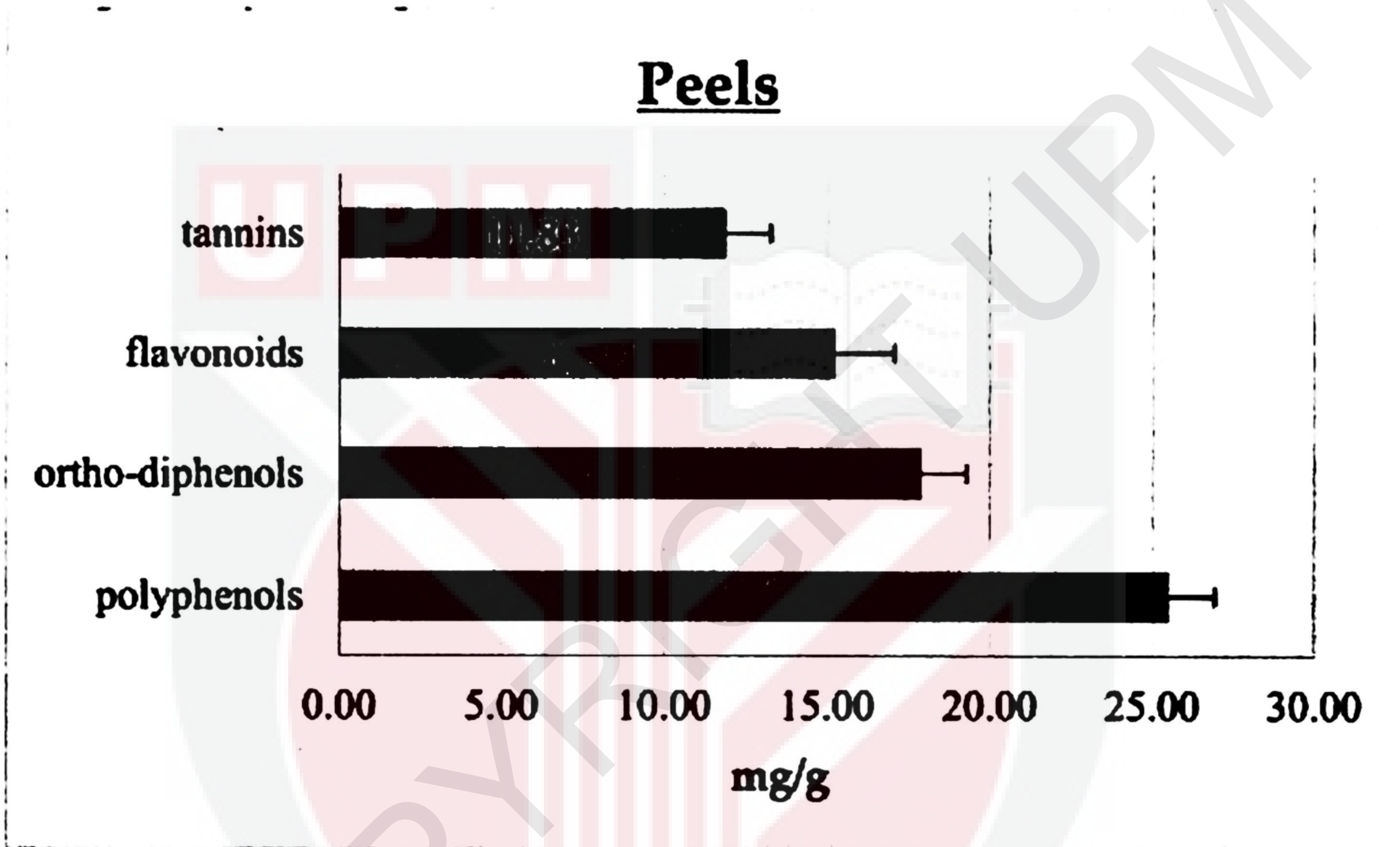


Figure 2.3: Polyohenol, ortho-diphenol, flavonoid and tannin contents in muskmelon peels. (Vella et al.,2019).

In peels, the polyphenol content was 25.48, is the highest. Then, ortho-diphenols, 17.86, flavonoids, 15.19 and tannins, 11.83. From the data, the seeds have several benefits that can be used by developing new nutraceuticals such as supplements, dietary and nutritional products.

Constituents	Nutritional values (%)
Total sugars	24.5
Reducing sugars	6.8
Non-reducing sugars	17.7
True protein	8.7
Phenolics	0.7
Total ash	14.9
Cellulose	14.8

Table 2.5: Nutritional values of different constituents from muskmelon peels (Bakshi & Wadha, 2013)

Muskmelon peels have high in total sugars percentage with 17.7% non-reducing sugars and 6.8 reducing sugars. The phenolics values are the lowest. From the table above, the peels have capability to be used as something beneficial such as livestock feed, supplements or else.

2.1.4 Processing and Applications

Fresh muskmelon has a delicate yet distinctive flavour that provides the fruit with a highly appropriate taste. Thermal processing is needed to for processing and preservation of muskmelon puree which affects the volatile constituents. It is important to understand the flavour changes that would affect the consistency of the processed and packed muskmelon during thermal processing. There are different methods of thermal processing for muskmelon puree such as heating, canning and packing in retort pouches (Priyanka et al., 2014).

Compound	Fresh	Heated	Retort pouch	Canned
Aldehydes	18.57	8.21	0.24	1.61
Esters	27.29	29.35	53.35	77
Aliphatic alcohols	11.72	25.12	1.21	2.61
Heterocyclic	16.63	1.91	2.14	4.81
Phenolic	6.03	2.15	1.92	2.48
Carboxylic	8.64	2.56	13.11	4.2
Alicyclic alcohol	0.26	Not detected	Not detected	0.13

Table 2.6: Composition of major volatile compounds in muskmelon puree with different treatments (Priyanka et al., 2014).

Thermal processed muskmelon puree in cans and retort pouches showed increase in the esters content to 29.35 %, the esters were found in the range of 77 % and 53.35 % respectively. High ester content in packaged puree as compared to fresh and heated samples could be due to the sealed packaging system of can which protected the esters. Aldehydes content (18.57 %) of fresh puree reduced to 8.21%in heated puree and further reduced in the canned (1.75 %) and retort (0.24 %) processed samples.

2.1.5 Potential application as substrate in bioethanol production

Bioethanol is one of the most important renewable energy fuels that contribute to the reduction of negative environmental impact. Ethanol is made from a variety of products such as grain, molasses, fruit, cobs, and shell; its production, excluding that of beverages, has been declining since the 1930s because of the low cost (Akpan et al., 2005). Nowadays, many countries have increased their bioethanol production. Brazil produces the maximum amount of ethanol (15,099 million liters/year) followed by the U.S. (13,381 million liters/year), China (3,649 million liters/year) and India (1,749 million liters/year) (Neelam et al., 2014).

According to Sarkar et al., 2012, Agricultural wastes are cost effective, renewable and abundant. Bioethanol from agricultural waste could be a promising technology (Kim and Dale, 2004). Salassi in 2007, report that about 60% of the global ethanol is produced from sugar crops and the remaining 40% is produced from starchy grains. Therefore, the melons peels as a waste has potential to be a substrate for bioethanol production.

Noura and Nithiya studied bioethanol production with batch fermentation of honeydew melon rinds syrup. By using sterilized fruit's syrup was inoculated with *Aspergillus niger* in total volume og 100 mL. They were incubated in shake flask at constant agitation of 120 rpm at 30°C in various pH such as pH 4, pH 5, pH 6 and pH 7. Three biological replicates were conducted aseptically for each experiment for 7days (120 hours).

Production of ethanol (in %)					
pH/Hours	24	48	72	96	120
4	5.05	9.35	19.72	31.78	40.28
5	9.16	14.02	30.09	35.51	46.82
6	12.5	22.24	36.45	42.72	48.79
7	9.25	12.34	21.50	37.29	44.77

Table 2.7: Percentages of ethanol yield from honeydew melon rinds at 24 hours interval for 5days

2.3 Pre-treatments

Pre-treatment is widely used before drying of agro-products to inactivate enzymes, enhance drying process and improve quality of dried products. They include chemical solution (hyperosmotic, alkali, sulfite and acid, etc.) and gas (sulfur dioxide, carbon dioxide and ozone) treatments, thermal blanching (hot water, steam, super-heated steam impingement, ohmic and microwave heating, etc), and non-thermal process (ultrasound, freezing, pulsed electric field, and high hydrostatic pressure, etc) (Deng et al, .2017). Pre-treatment is needed to be done before drying process to increase drying rate, maintain quality and decrease microbial load of products.

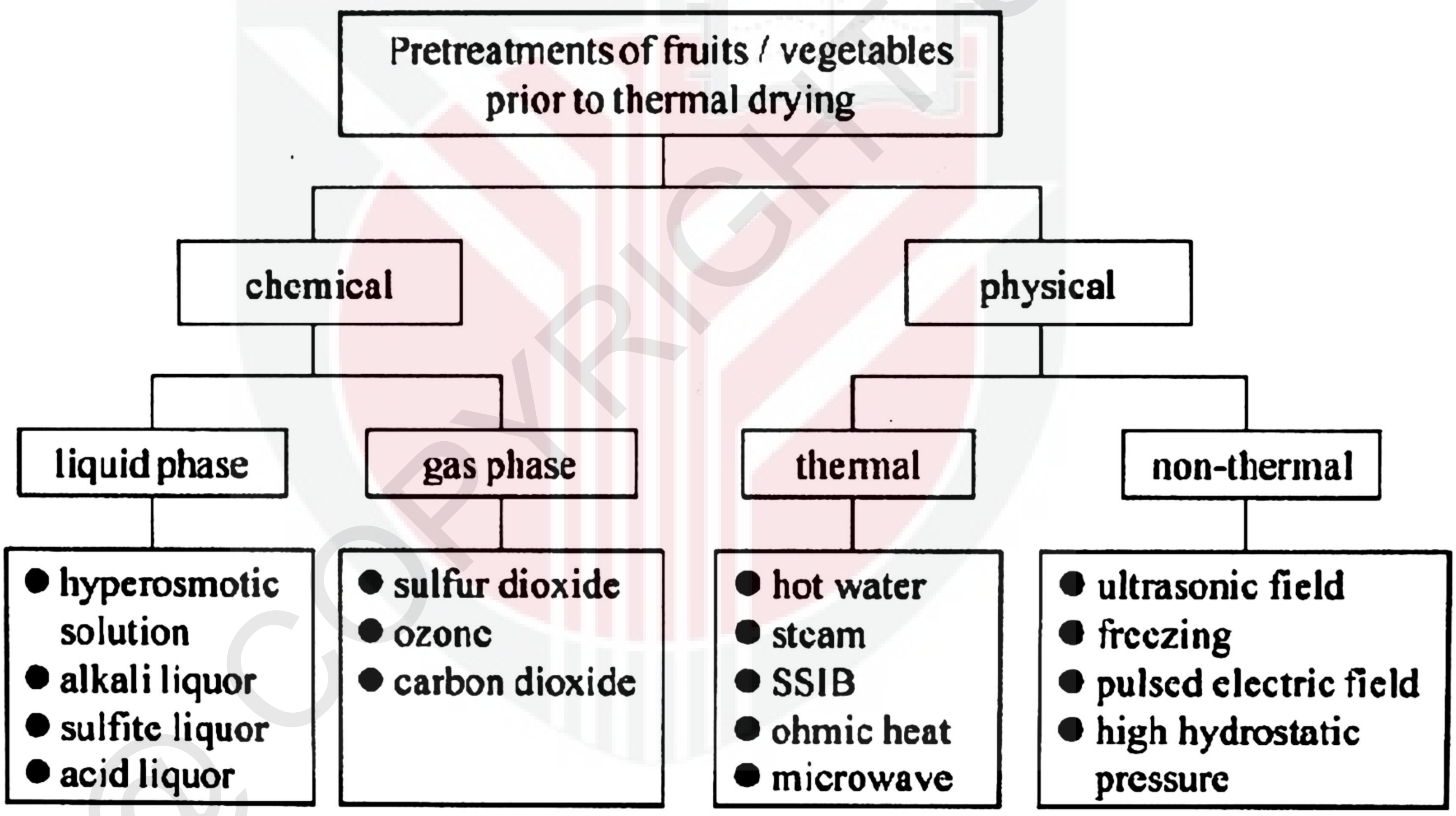


Figure 2.4: Pre-treatment methods of fruits or vegetables prior to thermal drying (Deng et al, .2017).

Fruits and vegetables are usually subjected to physical or chemical pretreatment before drying to shorten the drying time, reduce the energy consumption and preserve the quality of products (Yu et al., 2017). The drying rate and quality of products do largely relate to the pretreatments carried out before drying process (Fernandes & Rodrigues, 2008).

2.3.1 Acidic Solution

Acid pre-treatment regularly used in order to enhance the quality of the products by inactivating of enzymes, improving pigment stability and modifying texture of agro products. Moreover, the stability of pigments, such as betalains and anthocyanins, can be enhanced at acid condition (Ngamwonglumlert et al., 2016), and texture of product can be maintain by using acid solution, due to their chelating properties (Hiranvarachat et al., 2011). Chemical additives dipping techniques have advantages of enhancing drying process and maintaining quality of foods; while the residues in the food may cause food safety problems.

Citric acid, as an organic acid, is the most commonly used as anti-darkening agent and a texture-modifier of fruits and vegetables. Meanwhile, it has been confirmed that citric acid can accelerate the drying process, as pectin loosening in acidic environment, in turns promoting water removal (Hiranvarachat et al., 2011). A study made by Doymaz, Demir and Yildirim at 2015 regarding on the effect of pre-treatments on drying and rehydration characteristic concluded that when the product are pre-treated with citric acid (1:25 w/w) at 20°C for 1 minute can reduces drying time more than 16%. Other than that, Doymaz also made a study in 2014 by pre-treated tomatoes with citric acid solution (1:25 w/w) at 20°C for 1 minute then dried it with hot air drying. He founds that the pre-treatments increased water diffusivity, reduced drying time and improved rehydration ratio.

Furthermore, Ascorbic acid as an antioxidant can be used as pre-treatment before drying process, as it can reduce the oquinones to colorless dihydroxyphenols and form a barrier to oxygen diffusion into the products. Dipping banana in a solution containing 10 g/L ascorbic acid and 10 g/L citric acid for 1 minute can improve product colour, reduced freeze-drying time and shrinkage (Pan et al., 2008). Generally, the ascorbic acid is considered less effective in inhabiting enzymatic browning, attributes to its insufficient penetration into the cellular matrix, so it usually combined with citric acid (Deng et al., 2017). Zhu et al. (2007) found that combined ascorbic acid and citric acid was effective to slow down enzymatic browning rate of apple cubes.

Besides, some pigments are sensitive to acids, such as chlorophylls and carotenoids, using acid solution may cause the pigments degradation and colour change (Deng et al., 2017). For example, the chlorophylls are prone to be pheophytin at acidic condition, lead to the colour changes from green to olive brown (Ngamwonglumlert et al., 2016). Acid soaking significantly reduced the b-carotene retention of carrots by 29%–61%, as compared to water soaked samples (Hiranvarachat et al., 2011).

2.3.2 Physical pre-treatments: Blanching treatments

Thermal blanching is widely used prior to drying, its primary goal is to inactivate the enzymes involved in the spoilage of fresh agro-products, in addition to reduce the microbial load of products so as to improve its conservation, to soften tissues for facilitating drying process, and to eliminate intracellular air to prevent oxidation.

Coventional hot water blanching. Hot water blanching is a common pretreatment used prior to drying, it involves to immerse fresh products into hot water at a constant temperature ranging from 70 to 100 °C for several minutes (Guida et al., 2013). Generally, hot water blanching is used in order to retain the product quality by inactivating the enzymes, destroying microorganisms, or expelling intercellular air from the tissues (Mukherjee & Chattopadhyay, 2007). Meanwhile, it also helps to accelerate drying rate by changing the physical properties of the samples such as the permeability of the cell membranes (**Jangam, 2011**). Conventional hot water blanching popular and commonly used because of easy operation and simple equipment.

Steam blanching. Steam blanching can be used in order to minimize nutrients especially the water soluble nutrients and solid content dissolves into hot water and reduce the waste water. It is believed that the steam blanching contributes to retention of most minerals and water-soluble components as compared with water blanching, due to its negligible leaching effect (Deng et al, .2017). It was confirmed by Gamboa-Santos et al. (2012), that steam blanching gave rise to carrots with higher retention of vitamin C (81.2%) than those blanched in water at 60 °C (1.3%). Steam blanching increased the content of phytochemicals content in samples by enhanced extraction of these

components as a result of increased permeability of cellular membrane, such as phenols and ACNs in blueberries (Del et al., 2012).

2.4 Foam mat drying

Moderate thermal treatments are usually applied in order to extend the shelf life of fruits and vegetables. However, the processes may negatively affect the products quality. For example, heat processing can cause several biological, physical, chemical and microbiological changes. Foam mat drying is an economical to drum, spray and freeze-drying for the production of food powders (Sangamithra, Sivakumar, Swamy & Kannan, 2014). To obtain high quality of food powder, the selection of foaming method, foaming agents, foam stabilizers, time taken for foaming, suitable drying method and temperature need to be considered. When the surface area of the foam is large, the process of drying will be faster. Even though this method is cheaper than freeze and spray drying, it can be used in industries for large scale production of powders because of its retention of nutritional quality, easy reconstitution, rapid drying at lower temperature and cost effective for producing food powders.

2.4.1 Foam properties

Foam is colloidal dispersion in which gas is dispersed in a continuous liquid phase. The dispersed phase is referred as the internal phase and continuous phase is referred as the external phase (Laurier, 2014). The dispersed phase is larger than the continuous phase. Foams can be divided into two types (polyhedric foam and dilute bubbly foam). For polyhedric foams, the ratio of dispersed phase to continuous phase is large, then the number of bubbles is high. Egg white foam and beer foam are some of the examples of polyhedric foams. If the ratio is small, it is called dilute bubbly foams. Foam is a macroscopic dispersion of gas, whose existence and properties are controlled by colloidal forces, surface forces and interactions between the individual films separating gas bubbles (Indrawati and Narsimhan 2008; Narchi et al. 2009).

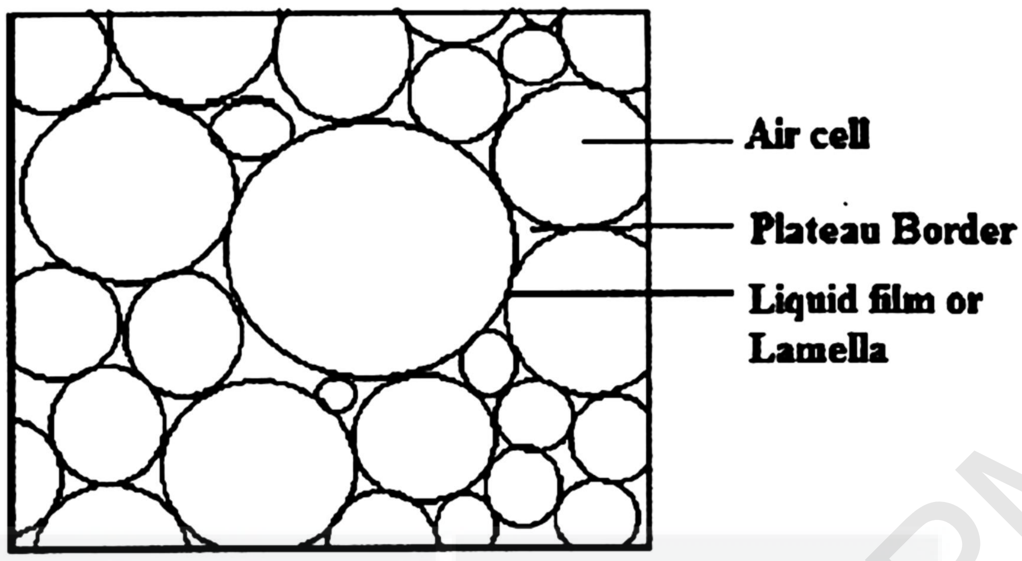


Figure 2.5: Schematic representation of structure of foam.

Some of foam properties need to be determined by using equations. For example, to determine foam density, foam drainage volume and foam expansion use different types of equation. Firstly, in order to find the foam density, the foam needs to be transferred without trapping the air voids and also without collapsing the foam structure into a standard measuring cylinder and weighed.

The main reason to determine foam drainage volume is to find out the stability of foam. It is also to indicate the rate of liquid drains from the foam. Buchner filter is needed to determine foam drainage volume. The juice is allowed to drain from the foam and the amount of juice will be collected under fixed time.

Then, foam expansion will be determined to study the percentage increase in volume of juice and to indicate the amount of air absorbed into the juice during whipping process.

2.4.2 Foaming agents

Foaming agents (surfactant material) that will reduces the surface tension between two liquids or between a liquid and a solid and facilitates the foam formation. A good foaming agent should be able to adsorb readily at the air-water interface, reduce interfacial tension, able to interact mutually among the proteins that unfold at the interface and form a strong cohesive, viscoelastic film that can withstand thermal and mechanical agitation proteins give a good foam ability and high foam stability through their hydrophobicity and possible conformational rearrangements, which allow rapid adsorption at the air-water interface leading to the formation of a coherent elastic adsorbed layer (Dickinson 1998). Moreover, protein foaming agents such as gelatin, egg white, milk proteins like casein, whey protein and soy protein. Protein foaming agents should possess the following properties, stabilize foams effectively and rapidly at low concentrations, perform effectively over the pH range and perform efficiently in the medium with foam inhibitors such as fat, alcohol or flavour substances.

Egg albumen is an example of foaming agent that is widely used to capture tiny air pockets in the mixture. Whipping process will cause the proteins of egg white denature at the interface and interact with one another to form stable, viscoelastic interfacial film. Egg albumin can be categorized as excellent food foaming agent. It has the ability to adsorb on the air-liquid interface rapidly during whipping.

S. no.	Product	Foaming agent	Whipping time, min and speed, rpm	Drying, C	Reference
1	Star fruit	Methocel 65 HG, 0.1–0.5% w/w	4 min	AD, 70–90	Karim and Wai 1999
2	Cowpea	Egg albumin, 2.5–15% w/w GMS, 2.5–15% w/w	3–21min	AD, 60	Falade *et al.* 2003
3	Seabuckthorn	CMC, 0–3%	3 min	AD, 55	Kaushal *et al.* 2013
4	Banana	Egg albumin, 10g/100g SPI, 5g/100g WPC, 5g/100g	–	AD, 80	Thuwapanichayanan *et al.* 2012
5	Tomato	EA, 0–20%	5 min, 1,400 rpm	AD, 65–70	Kadam and Balasubramanian 2011
6	Mango	EA, 5–15% MC, 0.5%	–	AD, 60–75	Rajkumar *et al.* 2007
7	Bael	GMS, 0–8 g/100g MC, 0–1 g/100g	5,000 rpm	–	Bag *et al.* 2011
8	Pineapple	Tricalcium phosphate, 0–1% EA, 0–2% CMC, 0.25%	18,000 rpm	AD, 65–85	Kadam *et al.* 2012b
9	Mandarin	EA, 0–2% CMC, 0–1% Milk, 0–9%	–	AD, 65–85	Kadam *et al.* 2011
10	Papaya	EA, 5–20% w/w MC, 0–1% GMS, 1–4%	10–15 min	AD, 60–70	Kandasamy and Varadharaju 2014
11	Apple	Gelatin, 0–1.5% w/w	3–9 min, 2,300 rpm	AD, 60	Valenzuela and Aguilera 2013
12	Shrimp	XG, 0.1%	5 min , 1,500 rpm	AD, 50–70	Azizpour *et al.* 2013
13	Malabar Tamarind	Methocel, 1% w/v	30 min	AD, 70	Phaechamud *et al.* 2012
14	Yogurt	MC, 0.5–2% EA, 1–4%	12 min	AD, 50–70	Krasaekoopt and Bhatia 2012
15	Tamarind	Ovalbumin, 1% Mesquite gum, 3% Surface active compound blend, 0.5%	4,600 rpm	AD, 50	Vernon-Carter *et al.* 2001
16	Plantain	GMS, 0.005–0.02%	3–18 min	60–80	Falade and Okocha 2012
17	Tomato paste	Myverol, 1%	–	AD, 71–82 MWD, 0–2.5 kW	Brygidyr *et al.* 1977
18	Blue Honeysuckle berry	GMS, 6% SPI, 3% CMC, 0.5%	2 min , 360 radian/min	MWD, 140–700 W	Zheng *et al.* 2013
19	Blackcurrant	GMS, 3% SPI, 1.5% CMC, 0.5%	–	MWD, 140–700 W	Zheng *et al.* 2011
20	Apple	EA, 3% MC, 1%	–	FD, 20C, 48 h	Raharitsifa and Ratti 2010a
21	Egg White	XG, 0.125–1% Glycol Alginate, 0.25–1% MC, 0.25–1%	5, 4,000 rpm	FD, 20C, 24 h	Muthukumaran 2007

Figure 2.6: Foaming and drying parameters used for various food materials

2.5 Air Frying drying

Air frying is a modern technique of baking, requiring quick circulation of air. An air fryer is for drying and baking. Hot air circulates rapidly to maintain a uniform temperature. The cooking chamber of an air fryer receives heat from the heating element close to the sample, hence the duration of cooking is shortened (Rahman et al., 2017). The presence of air flow modulates the temperature by releasing the hot air within the chamber and enhances the baking cycles and decrease baking time. A lower baking temperature in the presence of air flow is more efficient in terms of working time (Sani *et al.,* 2014). Hence, drying by air fryer can be differed from hot air drying or convective drying because of the difference in the manner air flows inside the air frying equipment.

2.5.1 Effects of air frying

Run	Parameters		Responses			
			Peeled pumpkin	Unpeeled pumpkin	Peeled pumpkin powder	Unpeeled pumpkin powder
	Temperature (°C)	Time (min)	MC (%)			
1	130	25	45.92	43.47	44.23	44.47
2	130	30	44.55	42.28	43.59	43.78
3	130	35	43.63	41.18	42.72	42.18
4	140	25	40.84	40.47	40.39	41.27
5	140	30	40.62	39.35	38.64	39.95
6	140	30	39.90	38.85	38.91	38.85
7	140	30	39.00	39.08	39.18	39.08
8	140	30	39.56	39.26	39.89	39.46
9	140	30	39.25	39.12	39.24	38.75
10	140	35	38.98	37.49	37.45	37.41
11	150	25	38.12	34.65	36.46	36.49
12	150	30	37.12	33.29	34.19	35.23
13	150	35	35.60	30.60	33.06	34.60

Table 2.8: moisture content analysis of drying pumpkin by air fryer (Rahman et al., 2020)

From the table above, moisture content is the most essential criterion and it is closely associated with the quality and texture of the food products. Before baking, the initial moisture content of the batter was standardised to the value of 48.75 ± 0.12% (wet basis). The final moisture content of all the 'bingka' samples is between 30% and 45% (wet basis). The 'bingka' baked at 150 °C in the air fryer resulted in low moisture content (30.60%) at 35 min as compared to baking at a lower temperature (130 °C) (Rahman et al., 2020). From the statement given, it proves that the high temperature of the air fryer can affect the quality of products by decreasing the moisture content during drying processes. Other than, if the temperature were fixed and the time are varies, it also can affect the quality. The longer the drying time, the higher losses of moisture contents.

The evolution of color is considered as one of the most important quality characteristics of food products. The value of lightness (L*), redness (a*), and yellowness (b*) will be measured.

Sample	**L***	**a***	**b***	**Chroma**	**Hueangle**	**ΔE**
Fresh	68.972	18.213	49.818	53.043	69.918	
Dried (30°C)	65.320	24.290	52.413	57.767	65.135	7.550
Dried (70°C)	63.385	28.009	57.265	63.747	63.936	13.514
Freezedried	77.703	15.249	41.435	44.152	69.795	12.462

Table 2.9: Color of pumpkin before and after drying treatments (Guine & Barroca 2012)

The table above shows decrease of L coordinate and increase of a* and b* parameters, which turned the samples more reddish and yellowish as the temperature raises (Guine & Barroca 2012). From the values of chroma and hue angle for the fresh

and dried pumpkin is possible to see that the increase of temperature from 30 ∘C to 70 ∘C increased the colorsaturaion while diminished the hue angle.

CHAPTER 3

METHODOLOGY

3.1 Sample Preparation

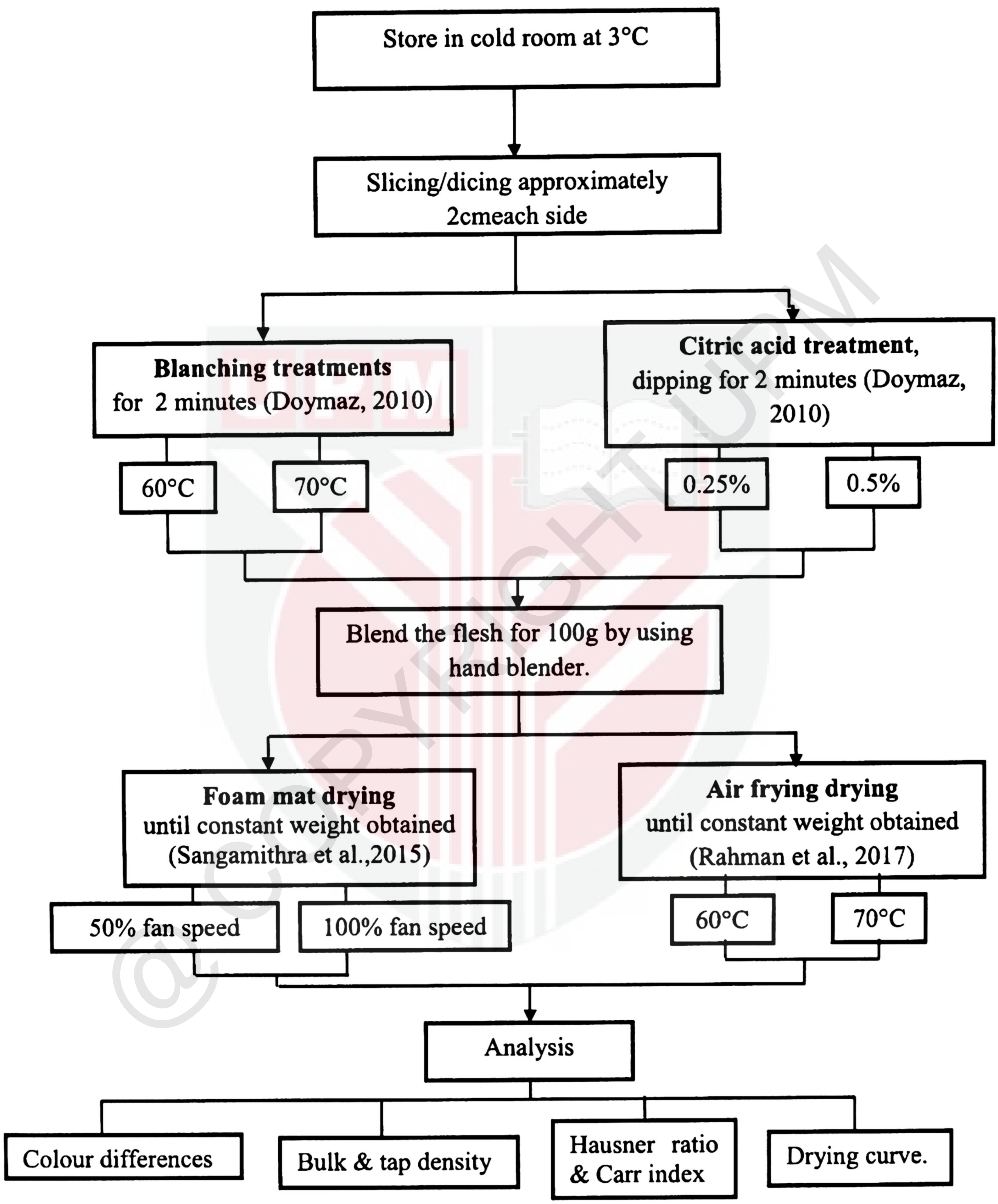
Muskmelon fruits were obtained from local supplier. The samples were stored in a cold room at 3°C until used. Before drying, the muskmelon were diced and peeled manually by using knife. The samples will undergo pre-treatment selected for the study. The selected pre-treatment can be observed from Table 3.1A.

Treatment	Description
Control blanch	Blanching the sample in hot water at 60°C& 70°C for 2 minutes and cooling immediately in tap water.
Citric Acid	Dipping for 2 minutes in solution of 0.5% & 0.25% citric acid at room temperature.

Table 3.1: List of pre-treatments with description

Then, the samples will blended in order to obtain the juices of muskmelon. 100 mL is needed for one sample. Duplicating the samples for precision on analysis of the products.

3.1.1 Flowchart of overall experiment



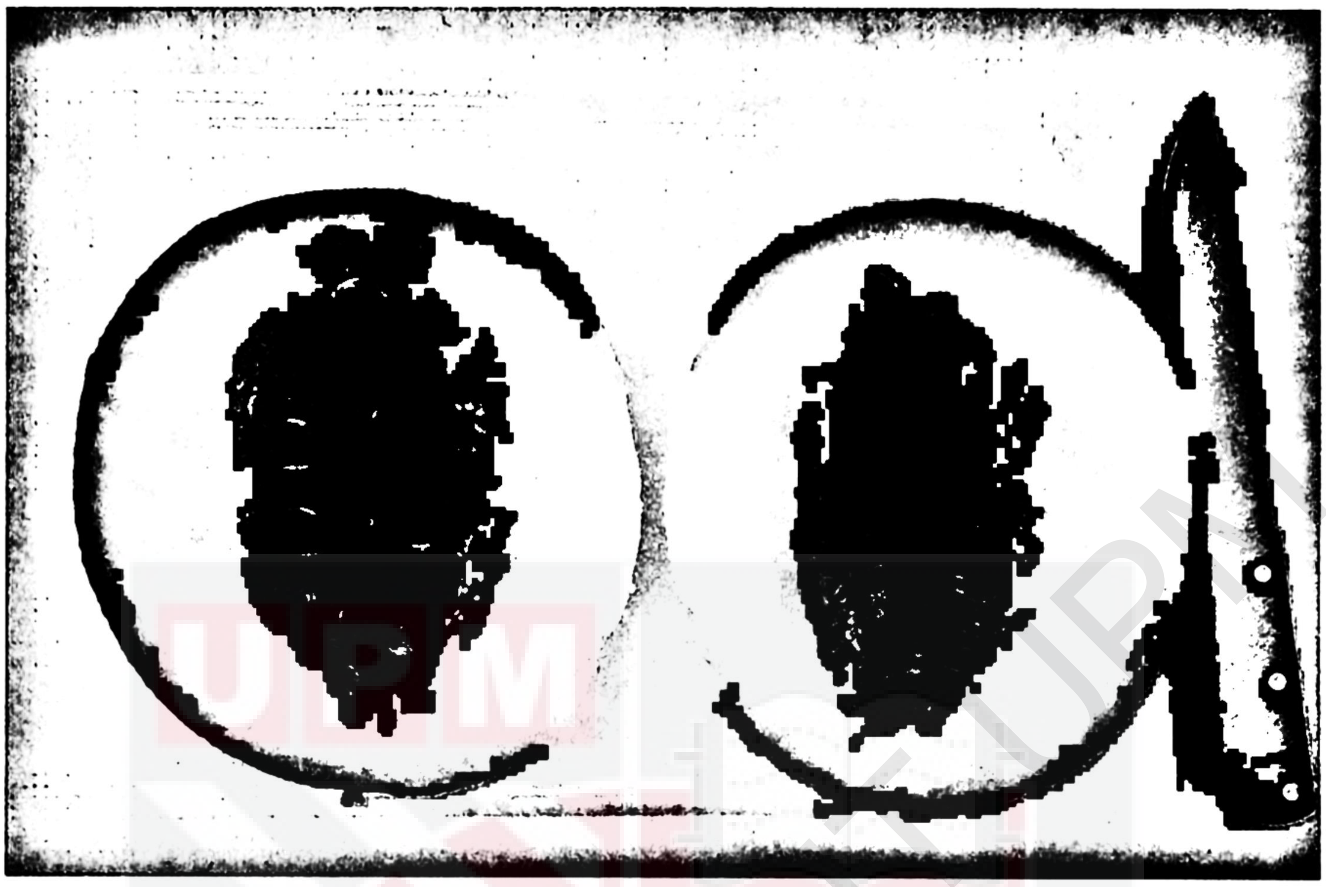


Figure 3.1: Half-cut muskmelon fruit

Figure 3.2: Diced muskmelon flesh

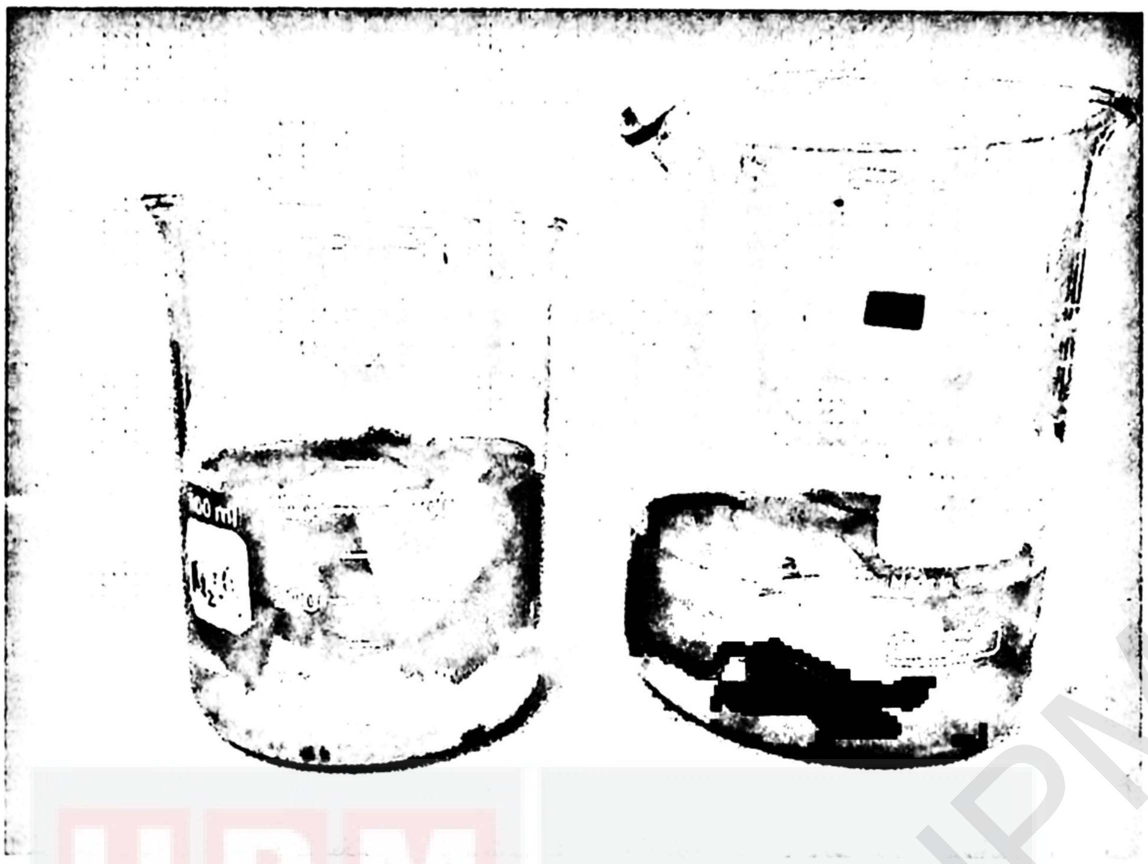


Figure 3.3: Muskmelon flesh dipped in acidic solution

Figure 3.4: Muskmelon flesh blanched in water bath

Figure 3.5: Blender used to blend muskmelon flesh

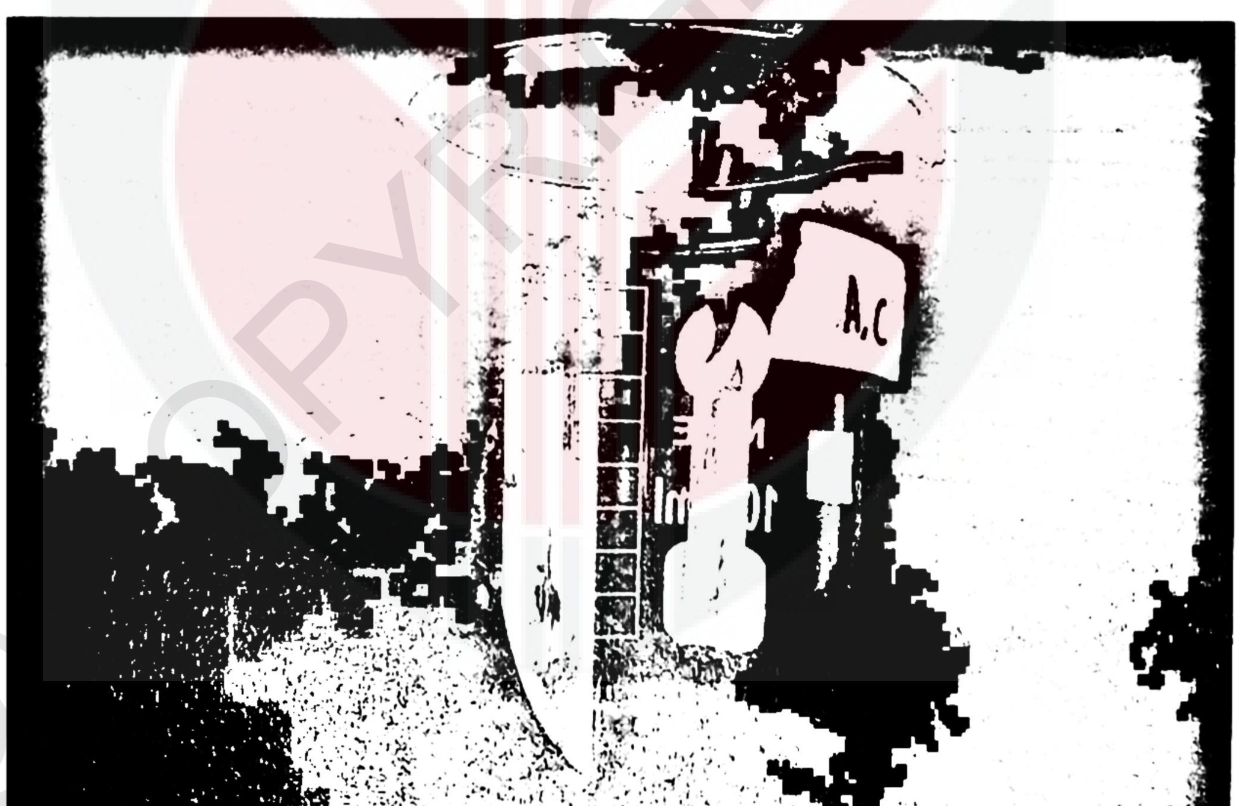


Figure 3.6: Blended muskmelon flesh

3.2 Foam mat drying

3.2.1 Preparation of muskmelon foam

For producing muskmelon foam, egg albumens were needed. Eggs were procured from the local market in Serdang, Malaysia. The egg albumen act as a foaming agent and food-grade carboxymethyl cellulose (CMC) will be used as a foam stabilizer at different concentration. Then, the egg albumen will be separated from the yolk using yolk separator to be use in the experiments. After that, 100mL muskmelon juice will be mixed with foaming agent and foam stabilizer inside mixing bowl. The mixture will be whipped using a hand blender. The foam will be transferred to further procedure.

3.2.2 Tray drier

A tray drier from University Putra Malaysia (UPM) was used in order to dry the foamed muskmelon efficiently with two different temperatures i.e. 42°C and 34°C. The fan speed of the tray drier also varied (50% and 100% fan speed). The velocity of air generated by the fan and temperature generated were determined using HANNA, thermo hygrometer, Model HI 9564,Europe,Romania. The foamed muskmelon was spread uniformly on a stainless steel tray and kept in drying chamber. Then, the weight was recorded at every 10 minutes using digital balance. Drying process will be stopped when the weight of the samples recorded constant values. The powder was scraped from the tray, packed and stored for further studies. Flowchart below shows the overall process for foam mat drying.

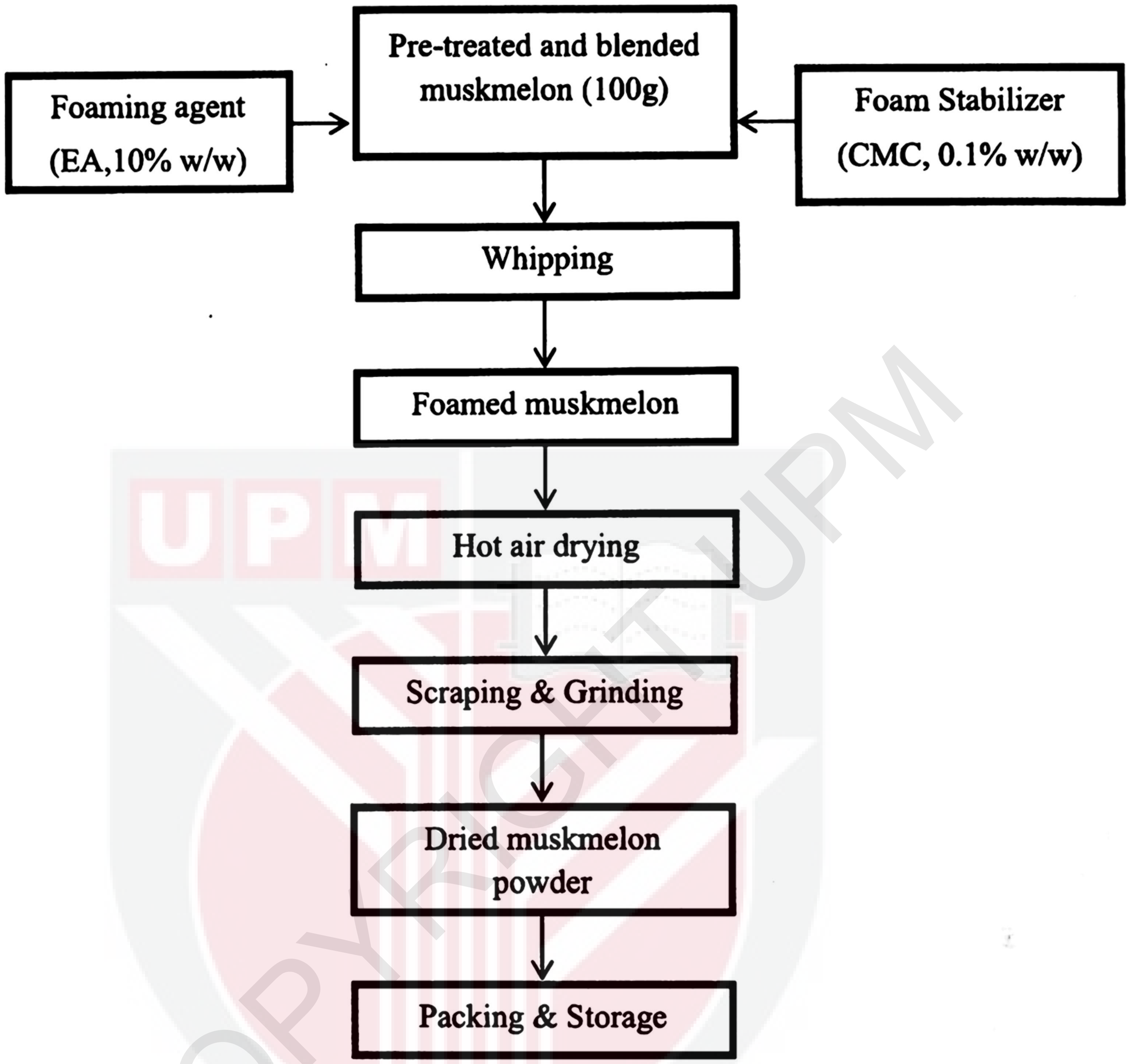

Foaming agent
(EA,10% w/w)
Pre-treated and blended muskmelon (100g)
Foam Stabilizer
(CMC, 0.1% w/w)
Whipping
Foamed muskmelon
Hot air drying
Scraping & Grinding
Dried muskmelon powder
Packing & Storage

Figure 3.7: Setup of ingredients used for foaming process i.e. blended muskmelon, egg albumin and CMC

Figure 3.8: Automatic stand mixer used for foaming process

Figure 3.9: Foamed muskmelon

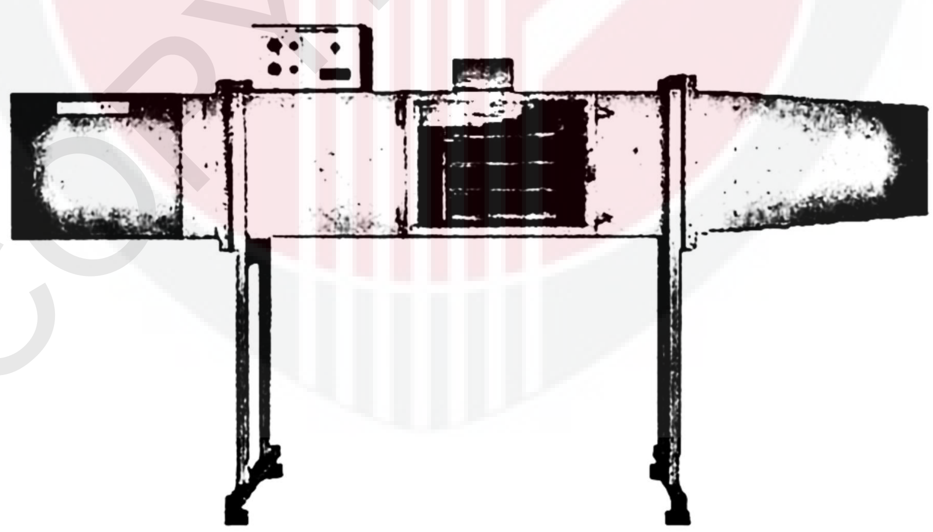


Figure 3.10: Tray drier used for drying process

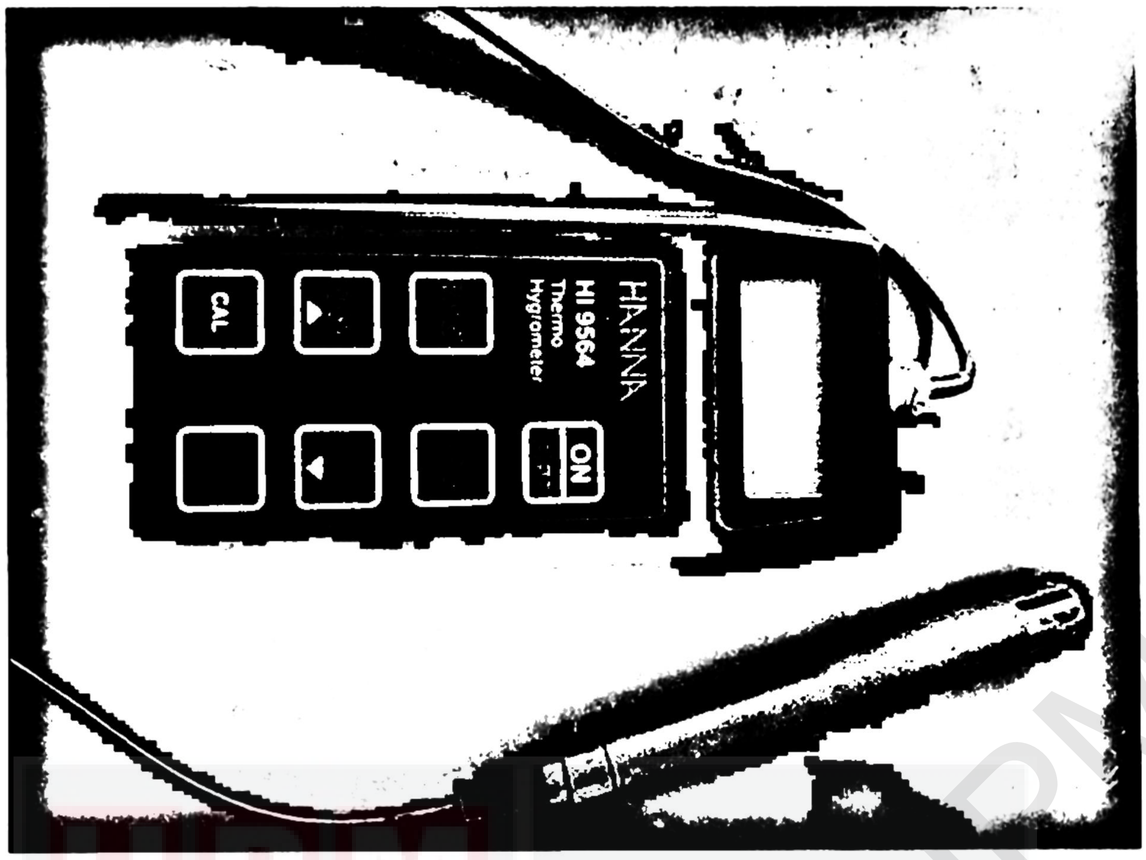
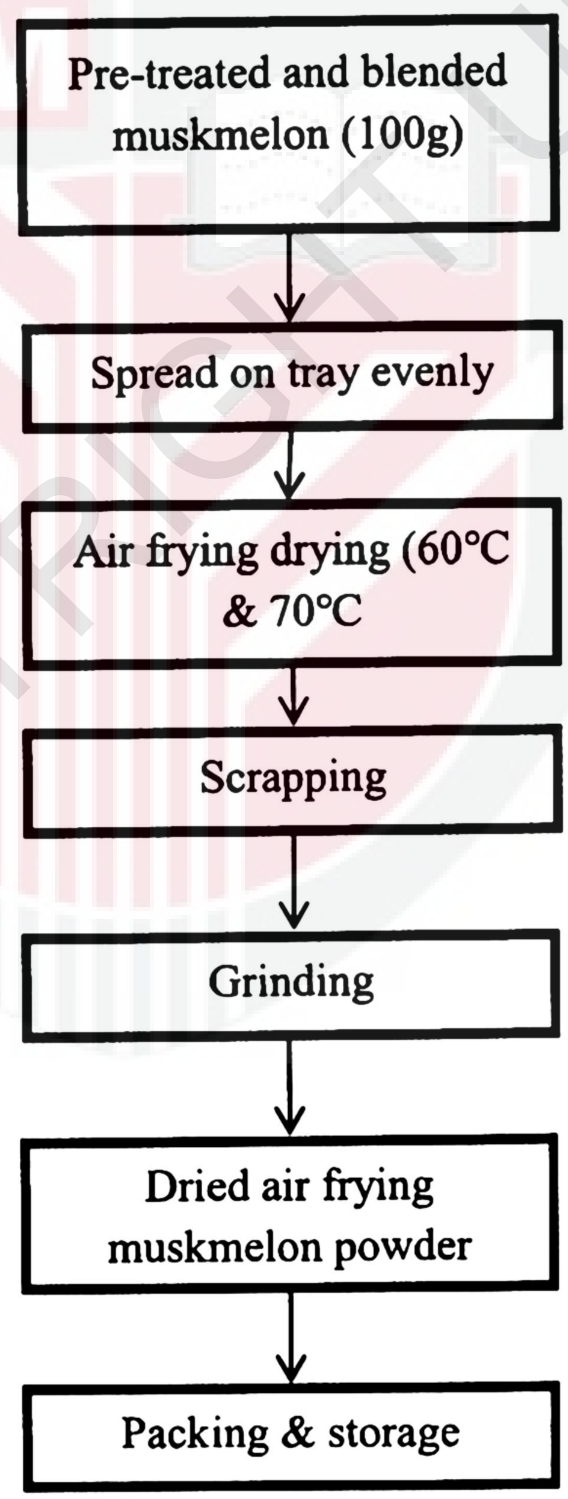


Figure 3.11: HANNA, Thermo Hygrometer, Model HI 9564, Europe, Romania

Figure 3.12: Dried muskmelon foam

3.3 Air frying drying

A commercial hot-fryer (Phillips, Model HD9220/20, United Kingdom) was used to dry blended muskmelon. Pre-treated muskmelon juice was pour into trays evenly. Then, it's placed inside the air fryer for drying. Two different temperatures were chosen i.e. 60°C and 70°C. The weights of samples were recorded every 10 minutes. Drying process was stopped when the weight's unchanged. Then, the dried muskmelon will be scraped from the tray and stored in a zipped-bag lock for further analysis.



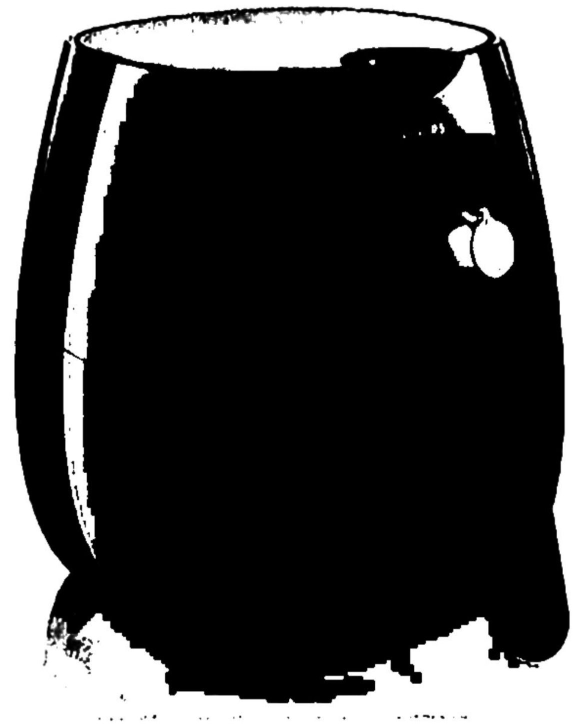


Figure 3.13: Air fryer, Phillips, Model HD9220/20, United Kingdom

3.4 Analysis

3.4.1 Moisture content

Moisture content of the products needs to be examined in order to achieve desired quality. A comparison of moisture content between before and after drying process. A&D moisture analyzer (model MX-50) was used to determine the moisture content. The data obtained was tabulated in the results section.

Figure 3.14: A&D moisture analyzer (model MX-50)

Moisture content (MC) of raw and dried muskmelon samples for each process condition were also calculated using the following equation:

$$MC = \frac{Mwet - Mdry}{Mdry}$$

Where M_{wet} and M_{dry} are the mass of samples before and after drying, respectively.

Figure 3.15: Moisture content analysis of muskmelon powder

Figure 3.16: Muskmelon powder after moisture content analysis

3.4.2 Color measurement

The color of the dried muskmelon powder and fresh muskmelon juice was measured using a colorimeter. Corresponding L* value represents lightness of color from 0 (black) to 100 (white); a* value represents the degree of redness (0 to 60) or greenness (0 to –60); and b* values represented yellowness (0 to 60) or blueness (0 to –60) were measured for all the samples. Calibration was performed using white colored tile prior to the analysis of sample.

Color analysis of the fresh and dried muskmelon was measured using handheld CR-14 Konican Minolta color reader. In this study, the L*, a*, b* and hue angle value was used to represent the color appearance of the samples.

Then the Chroma(C), Hue angle (h) and colour difference (ΔE) were calculated using following equations:

$$Chroma, C = \sqrt{a*^2 + b*^2}$$

$$Hue\ angle, h = \tan^{-1}\frac{b*}{a*}$$

$$Colour\ difference, \Delta E = \sqrt{\Delta L*^2 + \Delta a*^2 + \Delta b*^2}$$

3.4.3 Bulk and tap density

Standard measuring cylinder of known volume was taken and its empty weight was noted. The measuring cylinder was filled with the known weight of the muskmelon powder. The bulk density of the muskmelon powder was calculated by the following formula:

$$\text{Bulk density } (\rho_B) = \frac{\text{Mass of muskmelon powder, g}}{\text{Volume of muskmelon powder, cm}^3}$$

The tap density was determined by the method similar to bulk density, but after filling the measuring cylinder with known amount of powder, the cylinder was mechanically tapped. The new volume was recorded until it reached constant volume. The tap density was calculated by the following formula:

$$\text{Tap density } (\rho_T) = \frac{\text{Mass of muskmelon powder, g}}{\text{Final tapped volume, cm}^3}$$

3.4.4 Hausner ratio and Carr index

Hausner ratio is a number that is associated with the flow ability of a powder or granular material. It was calculated by the formula:

$$\text{Hausner ratio (HR)} = \frac{\rho_T}{\rho_B}$$

where ρT is the tapped density and ρB is the bulk density. The flow ability of powder was defined for different ranges of HR (Hayes 1987):

i. 1.0 < HR < 1.10, free-flowing powder

ii. 1.10 < HR < 1.25, medium-flowing powder

iii. 1.25 < HR < 1.4, difficult-flowing powder

iv. HR > 1.4, very difficult-flowing powder

Carr index represents the compressibility of a powder. It was calculated by the following formula:

$$\text{Carr index (CI)} = 100 \times \frac{\rho_T - \rho_B}{\rho_T}$$

An excellent flow ability may be expected if the CI is within 5–15%. If the value of CI exceeds above 25%, it indicates poor flow ability (Carr 1965).

CHAPTER 4

RESULTS AND DISSCUSSIONS

4.1 INTRODUCTION

Muskmelon having 91.24% of moisture content were used for the experiment. Flesh of ripe muskmelon fruits were diced (~2cm). The samples were pre-treated in 4 different ways such as, dipping in 0.25% and 0.5% citric acid for 2 minutes. Other two pre-treatments are blanching at 60°C and 70°C for 2 minutes. Then, the samples were blended using blender. After that, it will be dried using two different methods of drying, foam-mat drying (100% & 50% fan speed) and air frying drying (60°C and 70°C). Noted that the temperature of foam mat drying at 100% and 50% fan speed are 34°C and 42°C respectively. Next, after the samples were dried, it will undergoes analyses such as, colour analysis, bulk & tap density and the trend of drying curve will be observed. The analyses are to find out the effect of different pre-treatments on different parameters.

4.2 Effect of different pre-treatments on colour of dried muskmelon powder

Table 4.1 shows the effect of citric acid pre-treatment on color parameters of the muskmelon powder. While Table 4.2 shows the effect of blanch pre-treatment on colour of dried muskmelon powder for different drying methods (foam mat drying and air fry drying).

4.2.1 Effect of citric acid pre-treatment on colour of dried muskmelon powder

Samples	Colour			Chroma	Hue angle	Colour differences (ΔE)
	L*	a*	b*			
Foam-mat drying						
Controlled	31.90 ± 1.5	18.85 ± 1.0	25.5 ± 1.0	31.71	53.53	-
0.25% citric acid, 100% fan speed	28.65 ± 1.5	17.45 ± 1.0	26.7 ± 1.0	31.9	56.83	3.74
0.25% citric acid, 50% fan speed	29.45 ± 1.5	17.35 ± 1.0	28 ± 1.0	32.94	58.22	3.81
0.5% citric acid, 100% fan speed	29.35 ± 1.5	17.85 ± 1.0	27.3 ± 1.0	32.62	56.82	3.28
0.5% citric acid, 50% fan speed	29.80 ± 1.5	17.95 ± 1.0	25.85 ± 1.0	31.47	55.22	2.31
Air fryfry drying						
Controlled	17.50 ± 1.0	7.45 ± 1.0	20.75 ± 1.0	22.05	70.25	-
0.25% citric acid, 60°C drying temperature	17.70 ± 1.0	7.65 ± 1.0	22.15 ± 1.0	23.43	70.95	1.43
0.25% citric acid, 70°C drying temperature	17.85 ± 1.0	7.95 ± 1.0	22.00 ± 1.0	23.39	70.13	1.34
0.5% citric acid, 60°C drying temperature	18.10 ± 1.0	8.05 ± 1.0	21.95 ± 1.0	23.38	69.86	1.47
0.5% citric acid, 70°C drying temperature	17.55 ± 1.0	7.80 ± 1.0	21.75 ± 1.0	23.11	70.27	1.13

Table 4.1: Effect of citric acid pre-treatment on colour of dried muskmelon powder.

The values for the L*, a* and b* coordinates of the controlled samples are 31.9, 18.85 and 25.5 respectively for foam mat drying, 17.50, 7.45, 20.75 respectively for air fry drying. From the results, it shows that different drying method can affected the color parameters of the products. Muskmelon powder that dried by air fry drying were darker, less in redness (a*) and yellowness (b*) compared to powder that dried with foam mat drying. The lightness of products from foam mat drying are affected by the egg albumin that itself is white in color. Thus the foaming process increased the lightness in muskmelon powders. Air fry drying method produced darker products due to high temperature used.

The L value ranged from 17.50 to 31.90. It was observed that citric acid pre-treatments reduced the lightness and redness of the products compared to the controlled samples. But, the yellowness of the products slightly higher. The value of lightness, redness and yellowness of pre-treated products increase when using air fryer. The major causes of color change were to carotenoid degradation and non-enzymatic browning or Maillard reaction (Wang, Chao. 2002, Avila, Silva. 1999). It was also reported the reduction of L* value can be attributed to the formation of brown pigment during drying (Karabulut et al.,2007).

The chroma and hue angle values for controlled sample are 31.71 and 53.53 respectively for foam-mat drying, while 22.05 and 70.25 respectively for air fry drying. Chroma of air fry method is less than foam-mat drying due the product is less in saturation and color intensity. The hue angle of foam-mat drying is lower compared than air fry method because the colour is in yellow orange area, while for air frying the colour is in orange red area due to the darkness by drying. Citric acid pre-treatment does affected the chroma and hue angle values. The values are slightly higher compared to controlled samples.

The color difference values are high for foam-mat drying compared to air fry drying. The highest color difference is foam-mat drying, 0.25% citric acid pre-treatment and dried with 50% fan speed. The lowest color difference is air fry drying, 0.5% citric acid pre-treatment and dried with 70°C.

4.2.2 Effect of blanch pre-treatment on colour of dried muskmelon powder

Samples	Colour			Chroma	Hue angle	Colour differences (ΔE)
	L*	a*	b*			
Foam-mat drying						
Controlled	31.9 ± 1.5	18.85 ± 1.0	25.5 ± 1.0	31.71	53.53	-
Blanching 60°C, 100% fan speed	31.55 ± 1.5	15.65 ± 1.0	25.95 ± 1.0	30.3	58.91	3.25
Blanching 60°C, 50% fan speed	31.45 ± 1.5	15.85 ± 1.0	25.95 ± 1.0	30.4	58.58	3.07
Blanching 70°C, 100% fan speed	31.6 ± 1.5	17.85 ± 1.0	25.55 ± 1.0	31.17	55.06	1.05
Blanching 70°C, 50% fan speed	31.6 ± 1.5	15.65 ± 1.0	25.85 ± 1.0	30.22	58.81	3.23
Air fry drying						
Controlled	17.50 ± 1.0	7.45 ± 1.0	20.75 ± 1.0	22.05	70.25	-
Blanching 60°C, 60°C drying temperature	19.30 ± 1.0	8.40 ± 1.0	22.40 ± 1.0	23.92	69.44	2.62
Blanching 60°C, 70°C drying temperature	18.35 ± 1.0	7.95 ± 1.0	22.45 ± 1.0	23.82	70.50	1.97
Blanching 70°C, 60°C drying temperature	19.55 ± 1.0	8 ± 1.0	22.7 ± 1.0	24.07	70.59	2.88
Blanching 70°C, 70°C drying temperature	18.8 ± 1.0	7.75 ± 1.0	22.5 ± 1.0	23.84	71.03	2.24

Table 4.2: Effect of blanch pre-treatment on colour of dried muskmelon powder.

From table 4.2 shows the effect of blanch pre-treatments toward colour of muskmelon powder. The L* values slightly decreased for foam-mat drying compared to controlled samples, but increased for air fry drying. This is because the samples for air fry drying method become brighter when pre-treated by blanching. The a* values for air fry drying increased to show that it retained the redness colour, but when using foam mat drying the redness decreased. The b* values that indicates yellowness, shows increased in values for both drying method.

The results for chroma and hue angle show color stability for the samples dried at controlled conditions and an increase of the color intensity of the muskmelon when dried using pre-treatments. The hue angle of the samples shows that the colors are bright orange. There are slightly differences of hue angle value form the controlled samples. The total color difference ΔE, is a combination of L*, a* and b* values and a colorimetric parameter extensively used to characterize variation color in foods during processing. The color difference parameter has lowest value for 70°C blanch pre-treatments under 100% fan speed condition.

4.3 Effect of different pre-treatment on tapped and bulk density of dried muskmelon powder

Table 4.3 and 4.4 shows the bulk and tap density of dried samples when using foam mat drying and air fry drying methods and citric acid and blanch pre-treatments.

4.3.1 Effect of citric acid pre-treatment on tapped and bulk density of dried muskmelon powder

Samples	Drying Temperature (°C)	Weight (g)		Volume (mL)		Bulk Density (g/cm^3)	Tap Density (g/cm^3)
		Before	After	Before	After		
Foam mat drying							
CONTROLLED	34°C	5.051	5.051	16	14	0.316	0.361
0.25% Citric acid, 100% fan speed	34°C	4.554	4.554	19	16	0.240	0.285
0.25% Citric acid, 50% fan speed	42°C	4.255	4.255	16	13	0.266	0.355
0.5% Citric acid, 100% fan speed	34°C	3.308	3.308	15	12	0.221	0.276
0.5% Citric acid, 50% fan speed	42°C	4.342	4.342	18	14	0.241	0.310
Air fry drying							
Controlled	60°C	4.834	4.834	15	12	0.322	0.403
0.25% Citric acid	60°C	4.563	4.563	21	15	0.217	0.304
0.25% Citric acid	70°C	4.280	4.280	18	13	0.238	0.329
0.5% Citric acid	60°C	4.322	4.322	19	14	0.227	0.309
0.5% Citric acid	70°C	4.456	4.456	19	14	0.235	0.318

Table 4.3: Bulk and tap density of citric acid pre-treated muskmelon powder.

4.2.2 Effect of blanch pre-treatment on bulk and tapped density of dried muskmelon powder

Samples	Drying Temperature (°C)	Weight (g)		Volume (mL)		Bulk Density	Tap Density
		Before	After	Before	After		
Foam mat drying							
Controlled	34°C	5.051	5.051	16	14	0.316	0.361
Blanching 60°C, 100% fan speed	34°C	4.421	4.421	18	16	0.246	0.276
Blanching 60°C, 50% fan speed	42°C	4.544	4.544	19	17	0.239	0.267
Blanching 70°C, 100% fan speed	34°C	4.719	4.719	21	19	0.225	0.248
Blanching 70°C. 50% fan speed	42°C	4.677	4.677	20	18	0.234	0.260
Air fry drying							
CONTROLLED	60°C	4.834	4.834	15	12	0.322	0.403
Blanching 60°C	60°C	4.450	4.450	18	13	0.247	0.342
Blanching 60°C	70°C	4.561	4.561	19	14	0.240	0.326
Blanching 70°C	60°C	4.732	4.732	22	15	0.215	0.315
Blanching 70°C	70°C	4.654	4.654	21	14	0.222	0.332

Table 4.4: Bulk and tap density of blanched muskmelon powder.

Density is a crucial parameters affecting functional properties of powder. The bulk and tapped densities provide a perspective from packing and arrangement of the particles and the compaction profile of a material (Singh et al. 2010). The dried samples with air-fry drying powder developed in a very sticky and rubbery product. Therefore, the scraping of the controlled samples was found to be difficult.

Citric acid pre-treatment does affected bulk and tap densities by decreasing the values more than blanch pre-treatment.Furthermore, the bulk and tap density were found to decrease when pre-treated either with citric acid or blanching method compared to controlled samples. The results prove the pre-treatment enhancing the moisture loses during drying processes.

The values of bulk and tap density of controlled products for foam-mat drying are 0.316 and 0.361 respectively. For air fry drying, 0.322 and 0.403 respectively. This shows that the densities when using air fryer is higher compared when using foam-mat drying. The powders dried by air fryer are more sticky and clumped. This proves that foam mat drying method is better.

The values then used to calculate the flow ability of the products that shown in Table 4.5 and 4.6.This proves that the densities of the products does affected the flow ability.

4.4 Effect of different pre-treatments on Hausner ratio and Carr index of dried muskmelon powder

Table 4.5 and 4.6 shows the tabulated data of Hausner ratio and Carr index of samples with different citric acid and blanch pre-treatments and foam mat drying and air fry drying methods.

4.4.1 Effect of citric acid pre-treatment on Hausner ratio and Carr index of dried muskmelon powder

Samples	Hausner ratio	Carr index
Foam mat drying		
CONTROLLED	1.14	12.47
0.25% Citric acid, 100% fan speed	1.19	15.79
0.25% Citric acid, 50% fan speed	1.33	25.07
0.5% Citric acid, 100% fan speed	1.25	19.93
0.5% Citric acid, 50% fan speed	1.29	22.26
Air fry drying		
Controlled	1.25	20.10
0.25% citric acid	1.40	28.62
0.25% citric acid	1.38	27.66
0.5% citric acid	1.36	26.54
0.5% citric acid	1.35	26.10

Table 4.5: Values of Hausner ratio and Carr index for citric acid pre-treatment samples.

4.4.2 Effect of blanch pre-treatment on Hausner ratio and Carr index of dried muskmelon powder

Samples	Hausner ratio	Carr index
Foam mat drying		
CONTROLLED	1.14	12.47
Blanching 60°C, 100% fan speed	1.12	10.87
Blanching 60°C, 50% fan speed	1.12	10.48
Blanching 70°C, 100% fan speed	1.10	9.27
Blanching 70°C, 50% fan speed	1.11	10
Air fry drying		
Controlled	1.25	20.10
Blanching 60°C, 60°C drying temperature	1.38	27.78
Blanching 60°C, 70°C drying temperature	1.36	26.38
Blanching 70°C, 60°C drying temperature	1.47	31.75
Blanching 70°C, 70°C drying temperature	1.50	33.13

Table 4.6: Values of Hausner ratio and Carr index for blanch pre-treatment samples.

Hauner ratio and Carr index are important to indicate the flow ability of products. For foam-mat drying method, the controlled sample has 1.14 and 12.47 of Hausner ratio and Carr index respectively. The product is medium-flowing powder with below 1.25 Hausner ratio. The Carr index shows the powder is excellent in flow ability. While controlled sample for air fry drying is 1.25 and 20.10 respectively for Hausner ratio and Carr index. It is difficult-flowing powder and poor flow ability. This is due to the sticky behaviour of the products compared to foamed samples. A similar result was obtained for foam-mat drying of muskmelon (Sangamithra et al. 2015).

The samples that pre-treated with citric acid are increase in Hausner ratio and Carr index. Citric acid pre-treatment affect the flow ability of the powder become poor for both drying methods. For blanch pre-treatment, the values are slightly decreased. This shows that blanch treatment is better than citric acid treatment.

For different drying method, foam-mat drying method is better compared with air fry drying. This is due to large values of hausner ratio and carr index when drying with air fryer. This is because the products are sticky and causes poor flow ability.

4.5 Effect of pre-treatments on curve of muskmelon

Figure 4.7 and Figure 4.8 shows the effect of citric acid pre-treatment and blanch pre-treatment on the drying curves when dried with foam mat drying. While Figure 4.9 and Figure 4.10 shows, the effect of blanch pre-treatment on the drying curves when dried with air fry drying.

4.5.1 Effect of citric acid pre-treatment on drying curve of foam mat drying.

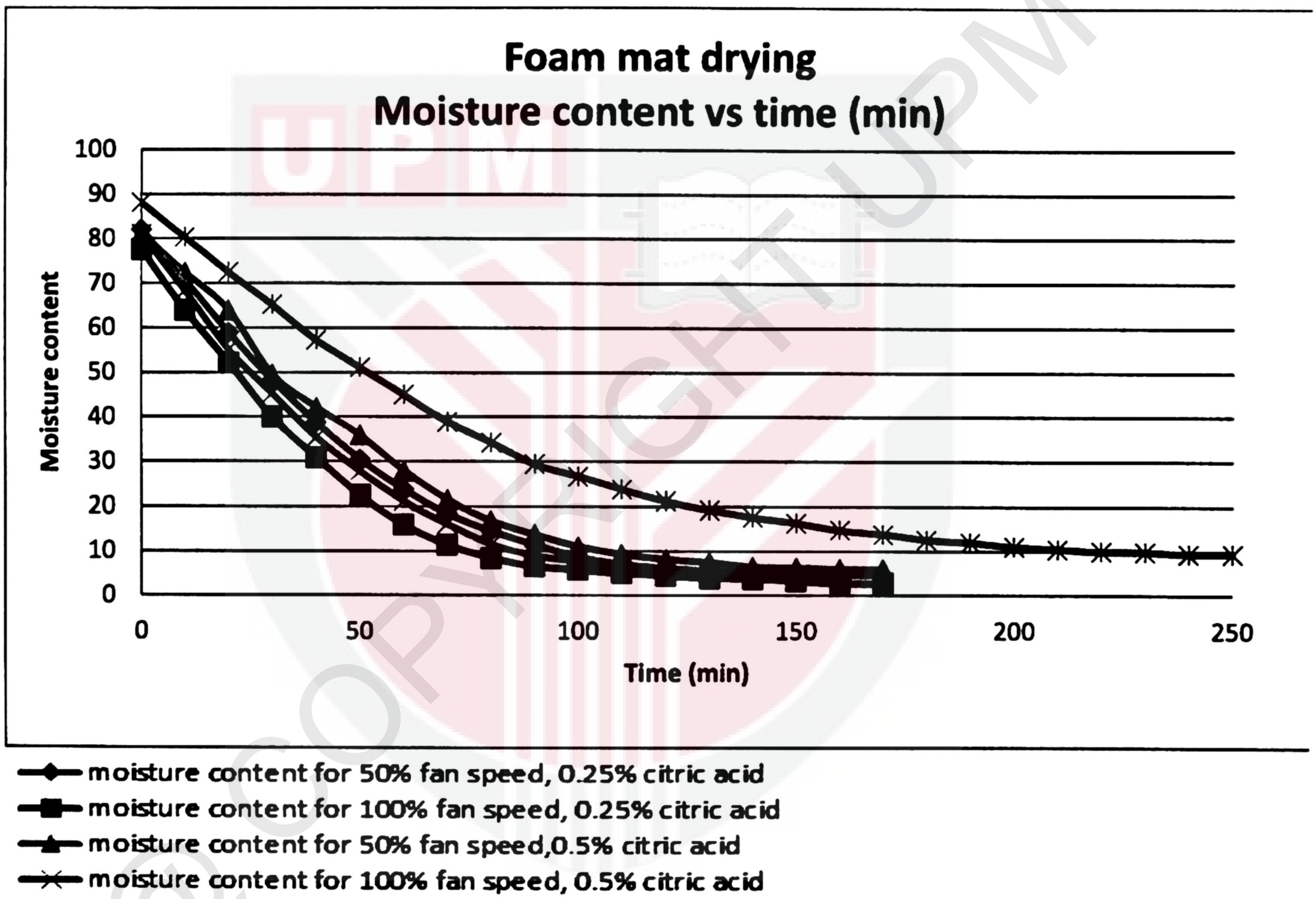


Figure 4.7: Drying curve of foam mat drying using citric acid pre-treatment.

Muskmelon having 91.24% moisture were used for this experiment. The effect of citric acid pre-treatment on foam mat dried muskmelon powder is illustrated in Figure 4.7 for different concentration (0.25% & 0.5%) and fan speed (50% & 100%). Moisture content decreased with increase time during drying. Moisture content also decreased with increase in fan speed percentage up to 100% after which the trend was observed. Foam mat drying of muskmelon took about 170 and 250 minutes for pre-treated samples and controlled sample respectively. The results obtained were generally in agreement with literature study on effect of citric acid on drying curve (Doymaz, 2010). It is evident that the pre-treatment of citric acid has effect on foam mat drying. There is huge different to complete drying process between pre-treated and controlled samples.

4.5.2 Effect of blanch pre-treatment on drying curve of foam mat drying.

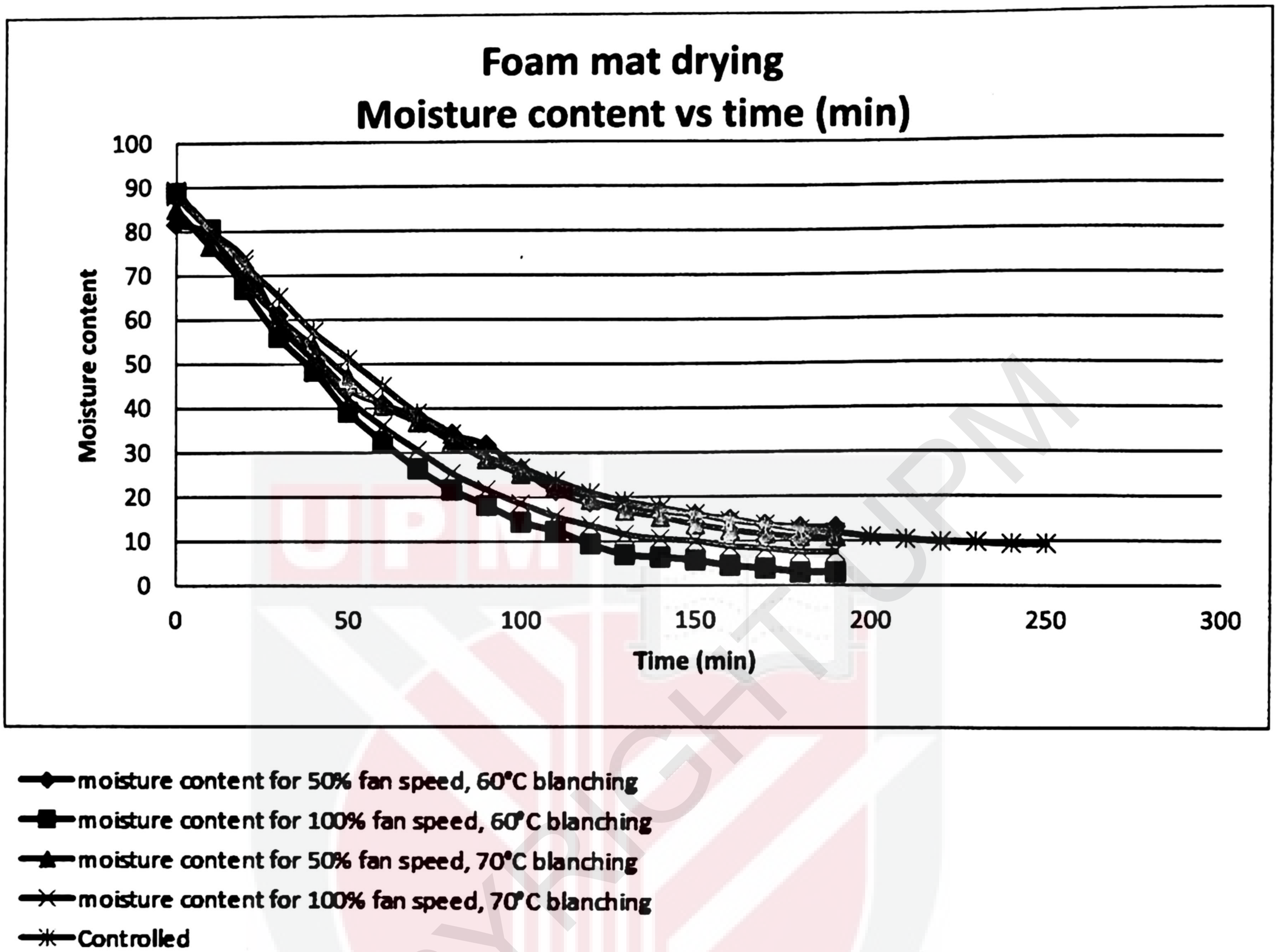


Figure 4.8: Drying curve of foam mat drying using blanch pre-treatment.

The effect of blanch pre-treatment on foam mat dried muskmelon powder is illustrated in Figure 4.8 for different blanching temperature (60°C & 70°C) and fan speed (50% & 100%). The moisture content decreased with increase of time. The drying curve also affected by the fan speed during drying process. The time to dry muskmelon samples are 190 minutes and 250 minutes for blanch pre-treated samples and controlled sample respectively. Similar results were reported for food products by earlier researcher (Doymaz, 2010).

4.5.3 Effect of citric acid pre-treatment on drying curve of air fry drying.

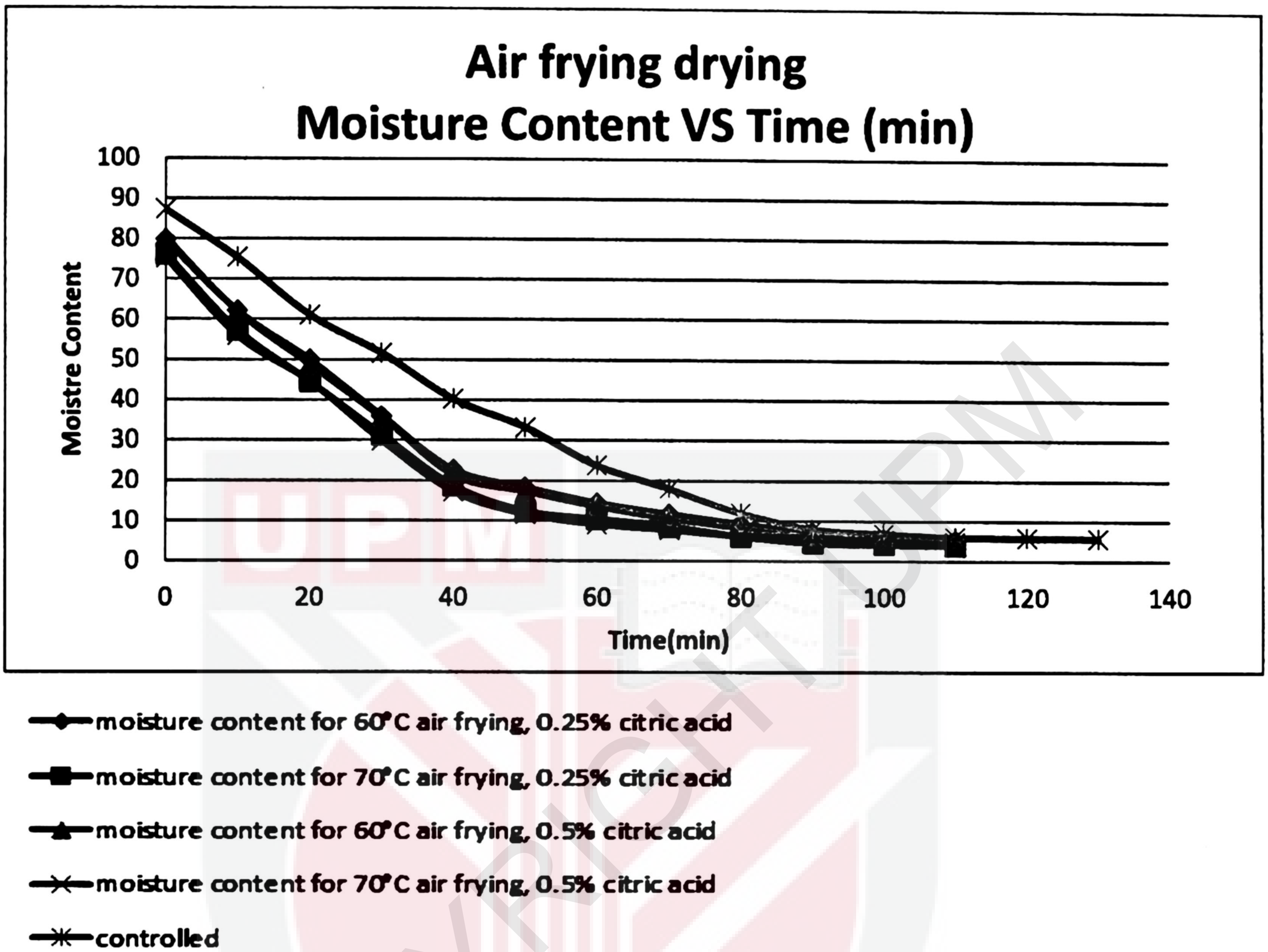


Figure 4.9: Drying curve of air fry drying using citric acid pre-treatment

From figure above, there are 5 different lines to indicate different samples. Four samples were treated with citric acid (2 samples with 0.25%, 2 samples with 0.5%) and the other one was controlled. The samples were dried with 2 different temperatures, 60°C and 70°C. Observation made from figure above were, the pre-treated samples lines were steeper than controlled lines. The times taken for the samples reach constant weight also less when pre-treated. This shows that, citric acid pre-treatment does decrease the time for drying. Other than that, the concentration of citric acid seems does not affect much on drying curves. The lines 60°C drying temperature for 0.25% and 0.5% citric acid are quite similar. The same case goes to 70°C drying temperature.

4.5.4 Effect of blanch pre-treatment on drying curve of air fry drying.

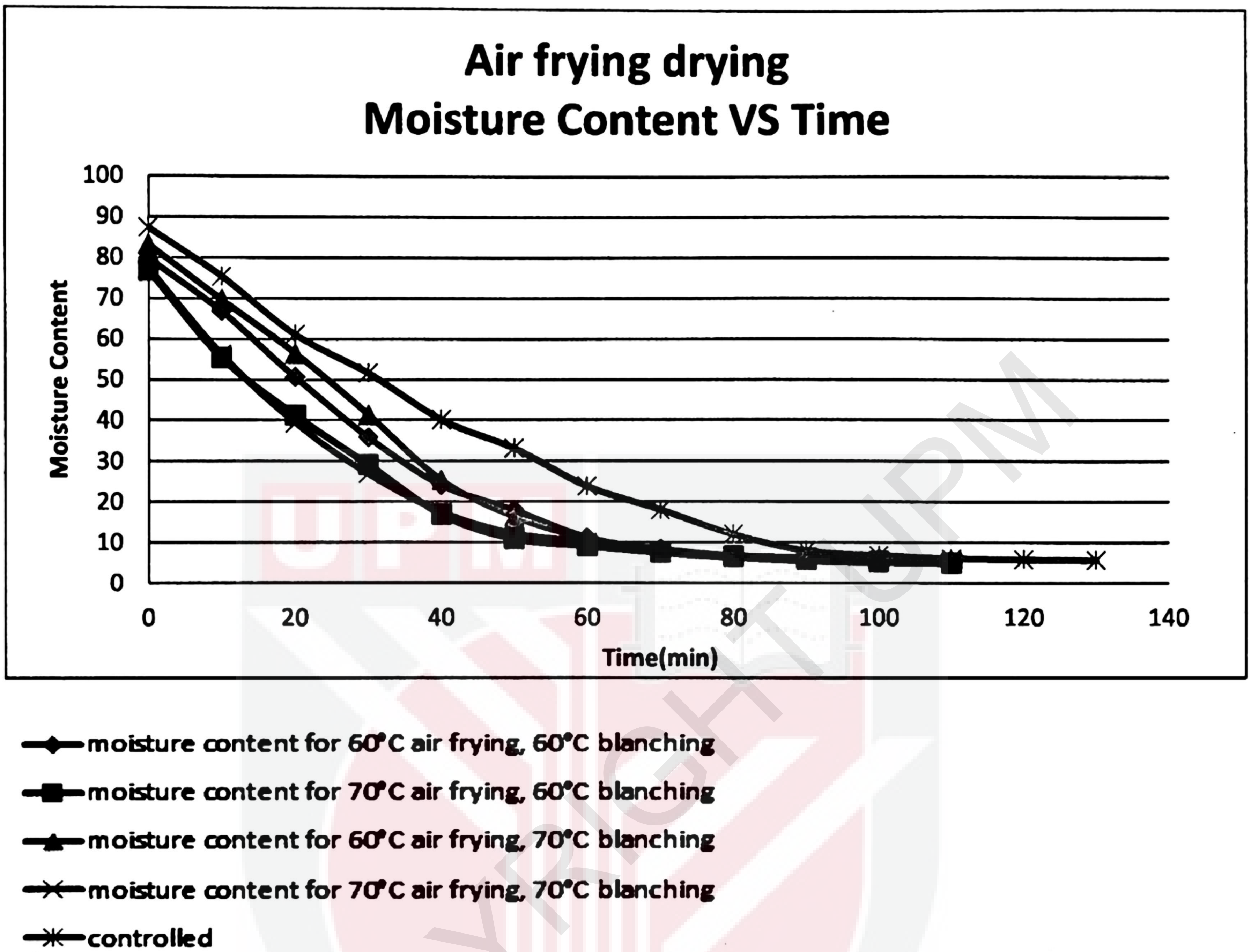


Figure 4.10: Drying curve of air fry drying using blanch pre-treatment

The effect of blanch pre-treatment to produce dried muskmelon powder by air fry is illustrated in Figure 4.10. The blanch pre-treatment does affect the drying time and the curve when compared to the controlled samples. The times to dry muskmelon are 110 and 130 minutes for blanch pre-treatment samples and controlled samples respectively. This proves that blanching affected the drying time and drying curves, but temperature for blanching does not affect much.

CHAPTER 5

CONCLUSION

The study has shown that different types of pre-treatment do affected the moisture content of powder, colour differences, bulk and tap densities, flow ability and drying curve. It was found that citric acid pre-treatment is better at retaining colour of powders when comparing with controlled samples and it reduces drying time that observed at drying curves but affected the powders become difficult-flowing powder. Then, blanch pre-treatment retained the colour of samples, reducing drying time and produces better flow ability powders than pre-treated with citric acid.

Other than that, foam mat drying does not change the colours much and produce better flow ability powders but has longer drying time. Air fry drying does have shorter time to dry compared to foam mat drying due to higher temperature, but the quality of the powder decreases and produced poor flow ability because of the sticky behaviour. Foam mat drying and blanch pre-treatment is the best combination to make the powder retained the colours and has better flow ability even though the time taken to dry the sample is longer.

Further future studies is needed on the chemical analysis, shelf life and nutritional values to have comparison of untreated and treated samples.

Appendices

Raw data of colour measurement of different pre-treatments.

I) Citric acid pre-treatment

SAMPLES	COLOUR		
	L*	a*	b*
Foam mat drying			
CONTROLLED	31.8	19.4	25.2
	32	18.3	25.8
0.25% citric acid 100% FAN	28.5	17.5	26.5
	28.8	17.4	26.9
0.25% citric acid 50% FAN	29.5	17.3	27.9
	29.4	17.4	28.1
0.5% citric acid 100% FAN	29.4	17.4	27.7
	29.3	18.3	26.9
0.5% citric acid 50% FAN	29.9	18.4	25.8
	29.7	17.5	25.9
Air fry drying			
0.25% citric acid, 60°C drying temperature	17.5	7.5	22.3
	17.9	7.8	22.0
0.25% citric acid, 70°C drying temperature	17.7	7.8	21.8
	18.0	8.1	22.2
0.5% citric acid, 60°C drying temperature	18.0	8.2	22.3
	18.2	7.9	21.6
0.5% citric acid, 70°C drying temperature	17.2	8.0	22.0
	17.9	7.6	21.5

II) Blanch pre-treatment

SAMPLES	COLOUR		
	L*	a*	b*
Foam mat drying			
CONTROLLED	31.8	19.4	25.2
	32	18.3	25.8
Blanching 60°C, 100% fan speed	31.5	15.5	25.5
	31.6	15.8	26.4
Blanching 60°C, 50% fan speed	31.5	16	26.1
	31.4	15.7	25.8
Blanching 70°C, 100% fan speed	31.3	18.9	25.3
	31.9	16.8	25.8
Blanching 70°C, 50% fan speed	31.7	15.3	26.1
	31.5	16	25.6
Air fry drying			
Blanching 60°C, 60°C drying temperature	19.2	8.3	22.5
	19.4	8.5	22.3
Blanching 60°C, 70°C drying temperature	18.2	8.0	22.5
	18.5	7.9	22.4
Blanching 70°C, 60°C drying temperature	19.5	8.2	22.6
	19.6	7.8	22.8
Blanching 70°C, 70°C drying temperature	18.7	7.8	22.5
	18.9	7.7	22.6

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