# Preparation of Mango Leather and Quality Analysis

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**A thesis submitted in fulfilment of the requirement for the degree of Bachelor Applied Science (Food Security) with Honours**

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# DECLARATION

I hereby declare that the work embodied in this report is the result of the original research and has not been submitted for a higher degree to any universities and institutions.

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I certify that the report of this final year project entitled "Preparation of Mango Leather and Quality Analysis" by Norazila Binti Miswan, matric number F18B0121 has been examined and all the correction recommended by examiner have been done for the degree of Bachelor of Applied Science (Food Security) with Honours, Faculty of Agro-Based Industry, Universiti Malaysia Kelantan.



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**Preparation of Mango Leather and Quality Analysis**

## Abstract

Fruit leather are dried fruits that use fresh fruit. This study used mango and jaggery in preparing the fruit leather. The objective of this studies was to determine the best formulation in producing mango leather and to determine the production quality of mango leather in terms of physical properties, colour and water activity, $a_w$. These studies used different percentages of jaggery which were 0 %, 10 %, 20 % and 30 % and different mango purees were 400 g, 360 g, 340 g and 280 g, respectively. Physical properties were analysed in terms of hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness by using Texture Analyzer CT3. In addition, the parameters for colour analysis L* a* b* were determined using Chroma Meter Konica Minolta CR-400, while the water activity, $a_w$ analysis was measured using Pawkit. Data were analysed using a t-test to determine whether there were significant differences in comparing the parameters between the two different formulations. Results showed hysical properties for hardness (24.00 g to 69.5 g), adhesiveness (0.03 mJ to 0.17 mJ), cohesiveness (0.70 J/m² to 1.19 J/m²), springiness (0.17 cm to 0.19 cm), gumminess (14.67 g to 66.33 g), chewiness (0.27 mJ to 0.93 mJ). For colour analysis, as the percentage of jaggery used increased, the lightness value (L*) for mango leather decreased, the value of yellowness (b*) decreased, while the value of redness (a*) increased. The analysis of water activity was in range (0.66 to 0.88) according to the drying process. Therefore, fruit leather made from the formulation of F3 has the acceptable quality of physical properties, colour, and water activity. In conclusion, this study proved that the fruit leather produced from mango and jaggery warranted research development for commercialisation purposes.

Keywords: Mango, jaggery, texture profile analysis, colour analysis, water activity, $a_w$

**Penyediaan Kepingan Mangga dan Analisis Kualiti**


## ABSTRAK

Kepingan buah ialah buah yang dikeringkan yang menggunakan buah buahan segar. kajian ini menggunakan buah mangga dan gula melaka dalam menyediaan Kepingan buah. Objektif kajian ini adalah untuk menentukan formulasi terbaik dalam menghasilkan kepingan mangga dan untuk menentukan kualiti pengeluaran kepingan mangga dari segi tekstur, warna dan aktiviti air, $a_w$. Kajian ini menggunakan peratusan gula melaka yang berbeza iaitu 0 %, 10%, 20 % dan 30 % dan puri mangga yang berbeza masing- masing adalah 400 g, 360 g, 340 g dan 280 g. Sifat fizikal telah dianalisis dari segi kekerasan, kelekatan, kepaduan, keanjalan, kelekitan and kekenyalan dengan menggunakan alat Texture Analyzer CT3. Selain itu, parameter untuk analisis warna L* a* bditentukan menggunakan Chroma Meter Konica Minolta CR-400, manakala aktiviti air, analisis $a_w$ diukur menggunakan Pawkit. Data dianalisis menggunakan ujian-t untuk menentukan sama ada terdapat perbezaan yang signifikan dalam parameter perbandingan antara dua formulasi berbeza. Keputusan daripada ciri-ciri fizikal untuk kekerasan (24.00 g hingga 69.5 g), kelekatan (0.03 mJ hingga 0.17 mJ), kepaduan (0.70 J/m² hingga 1.19 J/m²), keanjalan (0.17 cm hingga 0.19 cm), kelekitan (14.67 g hingga 66.33 g), kekenyalan (0.27 mJ hingga 0.93 mJ). Untuk analysis warna, nilai cahaya (L*) untuk kepingan mangga menurun mengikut peratusan gula melaka yang digunakan meningkat. Sementara itu, nilai kemerahan (a*) meningkat dan nilai kekuningan (b*) menurun. Berdasarkan ujian aktiviti air adalah terdiri daripada (0.66 to 0.88) mengikut proses pengeringan. Oleh itu, kepingan buah yang diperbuat daripada formulasi F3 mempunyai kualiti sifat fizikal, warna, dan aktiviti air yang boleh diterima. Kesimpulannya, kajian ini membuktikan bahawa kepingan buah yang dihasilkan daripada mangga dan jaggery memerlukan pembangunan penyelidikan untuk tujuan pengkomersilan..



Kata kunci: Mangga, gula melaka, analisis profil tekstur, analisis warna, aktiviti air,

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| L* | Lightness |
| a* | Redness – Greenness |
| b* | Yellowness - Blueness |
| cm | Centimetres |
| g | Gram |
| kg | Kilogram |
| Kcal | Kilo calories |
| KJ | Kilo joule |
| mg | Milligram |
| ml | Millilitres |
| mJ | Millijoule |
| $J/m^2$ | Joule per square metre |
| mm | millimetre |
| µg | microgram |
| IU | International Unit |
| $mm^3$ | cubic millimetre |

| | |
|---|---|
| mm/s | Millimetres Per Second |
| DOA | Department of Agriculture |
| FAO | Food and Agriculture Organization |
| FSSAI | Food Safety and Standards Authority of India |
| MADA | Agriculture Development Authority |
| DoSM | Department of Statistics Malaysia |
| USDA | U.S Department of Agriculture |

**LIST OF SYMBOLS**

| | |
|---|---|
| °C | Degree Celsius |
| % | Percentage |
| + | Plus |
| ≤ | Less than |
| > | More |
| ± | Plus minus |

# CHAPTER 1

# INTRODUCTION

## Research Background

*Mangifera indica* (mango) is a popular and a leading tropical fruit. Mango is high in prebiotic dietary fibre, vitamins, minerals, nutrients, and polyphenolic flavonoid antioxidant compound (Ara *et al.*, 2014). In Malaysia, around 300 varieties of mango are grown, each with its own growth pattern, yield, and quality characteristics (Muhamad *et al.*, 2019). The most popular mango plantation in Malaysia is located at Perlis, Kedah, Northern Perak, Melaka, Sarawak dan Selangor. The Department of Agriculture (DOA) reported that production of mango in 2019 is more than 16,508.54 metric tons from various types and varieties (DOA, 2020).

The fruits of most Mangifera species are edible. They have a sweet to sour flavour and can be eaten fresh or processed into jams or jellies (Salma, 2010). According to Muda Agriculture Development Authority (MADA), there are 77 varieties of Mangifera registered with the agriculture department. Among that, 5 of the varieties have been recommended which are MA128 Harumanis, MA162 Foo Fatt or Golek, MA165 MAHA, MA204 Melele L4 and LM2 MA224 Cokanan. Commonly, the variety of mango that popular in Malaysia are Harumanis and Cokanan (Bahri, 2013). The formation of the Food and Agro Council for Export (FACE) in 2014 enhanced the initiative to promote Malaysian-produced fruits for export by focusing on ten different types of fruits, including mangoes (Arshad *et al.*, 2020).

According of Department of Statistics Malaysia in 2016-2020, 70.0 percent of mangoes in Malaysia were imported from Thailand (DoSM., 2021). However, due to the movement control order (MCO), then were lots of unsold mangoes, since there were less customer visiting the market, compared to before the pandemic. These unsold mangoes will lastly turn to food waste which will give negative impact to environment, society and economy (Özbük *et al.*, 2020). One of the ways to tackle this issue is to convert the excess mangoes into mango-based product such as mango leather. According to Food and Agriculture Organization of the United Nations fruit leathers are dried sheets of fruit pulp which have a soft, rubbery texture and a sweet taste. It can also be eaten as snack foods instead of boiled sweets (FOA, 2011). This way, fruits would not be rotten in a week from their harvesting time. Furthermore, according to Diamante *et al.* (2014), consuming fruit leather as a source of numerous nutritional components is a cost-effective and easy value-added replacement for natural fruits.

## 1.2 Problem Statement

Most markets and supermarkets have to dump this mango because of its very short shelf life which made them easy to rot and finally turned into waste. Local producers were forced to sell these mango varieties at a low price, which will not be profitable for them. This indirectly affects the economic source for mango. Therefore, the way to reduce the waste is by producing mango fruit leather that meets consumer demand for health and nutrition. This product can indirectly maintain mango profits. This study was carried out to determine the best formulation to produce mango leather and determine the quality of mango leather production in terms of physical properties, colour, and water activity ($a_w$).

## 1.3 Hypothesis

**Ho:** Fruit leather made from mango had unacceptable quality of physical properties, colour, and water activity ($a_w$).

**$H_1$:** Fruit leather made from mango had acceptable quality of physical properties, colour, and water activity ($a_w$).

## 1.4 Objective of Research

The objectives of this study were:

i. To determine the best formulation to produce mango leather.
ii. To determine the quality of mango leather production in terms of physical properties, colour, and water activity ($a_w$).

## 1.5 Scope of Study

In this research, the study focused on the production and analysis of fruit leather with the variety of Chok Anan mango. First was the production of fruit leather from mango puree by determining four different formulations on the amounts of jaggery. Next, the quality of mango leather products was analysed based on the colour of the four mango leather formulations that were produced by using the Chroma Meter Konica Minolta CR-400. In addition, the water activity ($a_w$) of the mango leather was analysed by using PawKit tools. Finally, the texture of the four formulations of mango leather was analysed using Texture Analyzer (Brookfield CT3) to identify the hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness.

## 1.6 Significance of Study

The findings of this study were significant for local producers and the food industry to produce mango-based food products. This study provided knowledge to the local industry on ideas that can be applied for local product production and to expand the knowledge on local fruit. Further research in this field provided awareness of the mango commercial value as a tropical fruit with the potential to transform into a local product as well to increase economic productivity. This study also revealed the quality of this type of mango in the local food industry

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 *Mangifera Indica* (Mango)

### 2.1.1 Origin of Mango

*Mangifera indica* (mango) was first cultivated in the Indian subcontinent thousands of years ago (Tharanathan, 2006). In India, Bangladesh, Pakistan and Philippines, mango is the national fruit. Based on the extensive comparison between anatomy and morphology with fossil sample of species of genus Mangifera, the origin centre of mango is North– East India. Mangoes have been grown in South Asia for thousands of years, and they first arrived in Southeast Asia in the fifth and fourth centuries B.C. During 4000 B.C, mango is earliest mention as Mangifera indica in scripture of Hindu which means the great fruit bearer. Hills of Himalayan and Burma are the origins of wild mango and mango groves spreaded over many tropical and sub-tropical areas with years. Domestication of mango in India has been over 4000 years. In the last 25000 years, mango has been planted in subtropical regions introduced by traders, rulers, and travellers. Mango was taken to Malayan Peninsula and East Asia by Buddhist monks in

4th- 5th centuries (Mehta, 2017). Now the genus Mangifera comprises 69 species (Singh, 2012) majority of which can be found in the rain forests of Malaysia and Indonesia. Other than Malaysia, Indonesia especially Peninsular Malaya, Borneo, and Sumatra, also have the greatest diversity of wild mango species (Singh, 2016). These less excellently wild mango species is cultivated by Malayan villagers.

Figures 2.1.1: *Mangifera indica* (mango)

### 2.1.2 Taxonomy and Botanical

Mangifera is a genus in the Anacardiaceae family (Singh, 2016). Mangoes are known by many different names around the world now, reflecting the cultures and languages of those who develop them. The roots and spread of the mango tree, as well as the spread of human cultures, are reflected in many of the names. The mango tree is an evergreen orchard that grows quickly and lives a long time. Mango trees are long-lived evergreen trees that can attain heights of 15-30 meters. When fully mature, most cultivated mango trees are between 3 and 10 meters tall, depending on the variety and amount of pruning (Bally, 2006).

The mango tree is an evergreen broad canopy tree that can reach at height of 8–40 meters. The mango bark is a thick brown-grey colour with cracks on the surface. The leaves are 15 - 45 cm long and come in a variety of sizes. The length of the leaf petiole varies from 1 to 10 cm. Mango leaves come in a variety of forms: lanceolate, ovate-lanceolate, linear-oblong, roundish-oblong, oval, and oblong. Some mango varieties have green, red, and yellow leaves, with the upper leaf surfaces are usually shiny. The inflorescence is formed Male and hermaphrodite flowers are formed in the same panicle, which can range in diameter from 6 - 8 mm. In panicles, there are around 4000–5000 small flowers with red or purple spots on petals (Ediriweera *et al.*, 2017).

The mango fruit comes in hundreds of different varieties, each with its own characteristic aroma, shape, and scale. Each fruit measures is 5-15 centimetres in length and 4 -10 centimeters in diameter. Its weight usually varies from 150 g to 750 g, with the Sicilian mango fruit weighing about 390 g. Meanwhile, in unripe mangoes, the outer peel (exocarp) is smooth and green, but in ripe fruits, it turns golden yellow, crimson red, yellow, or orange red, depending on the cultivar type (Lauricella *et al.*, 2017). The endocarp is a massive ovoid-oblong core with a single seed within and it contains a thick yellow pulp (Shah, 2010).

### 2.1.3 Climacteric Fruit

Fruit ripening is a complex process, the physiological process of fleshy fruit ripening occurs until the end of the life cycle of the fruit (Busatto, 2017). Fruit with flesh has three stages namely different fruit sets, fruit development, and fruit ripening (Tripathi, 2016). The unique coordination of developmental and biochemical pathways that lead to changes in colour, texture, aroma, and nutritional quality of mature seed-bearing plant organs is represented by the ripening of fleshy fruits (Kou, 2018). Fruits are classified as climacteric or non-climacteric depending on the type of maturation and ripening, they undergo. Climacteric fruits, also known as ethylene-dependent fruits, can ripen after being harvested mainly to ethylene production. The commencement of ripening is indicated by a dramatic rise in respiration and ethylene evolution in climacteric fruits such as banana, tomato, avocado, and apple. Climacteric fruits can ripen after being removed from the parent plant, whereas non-climacteric fruits cannot. Strawberry, grape, raspberry, and citrus fruits are distinguished by the absence of an ethylene-related respiratory peak and by the absence of a climacteric increase in ethylene evolution (Fuentes, 2019).

Mango also known as climacteric fruit. When they are physiologically mature but before the climacteric rising, they are frequently harvested at the hard green stage (unripe) (Rooban, 2016). Since the ripening process begins quickly after harvest, depending on the cultivar, stage of maturity at harvest, and postharvest conditions, postharvest life is short (Kour, 2018). Some physio-chemical changes may occur in mango during ripening, resulting in softening of the fruit, a change in colour and flavour, an increase in sugar content, a reduction in organic acids, and the synthesis of pigments, particularly carotenoids (Rooban, 2016).

### 2.1.4 Nutritional Value

Fruits affect human's nutrition by providing additional sources of energy, growth factors, carbohydrates, dietary fibres, and antioxidants, all of which are essential for preserving normal health (Dar, 2016). Mango is a nutritious fruit that is high in carbohydrates, dietary fibre (pectin), vitamin C, and a variety of phytochemicals that help to maintain normal health (Maldonado-Celis, 2019). Table 2.1 shows the raw mango composition per 100 g and per serving size (one cup or 165 g).

According to report by Zafar (2017), some differences can be expected in the composition of mango fruit and its processed products from different regions. This is due to variable climatic and soil conditions, agricultural practices, postharvest handling, and processing methods. The peel or the skin of fully ripe mangoes is considered to be high in nutrients including terpenoids, but it is not eaten due to its unpleasant taste.

Table 2.1.3: Proximate, mineral, and vitamins composition of raw mangoes

| Composition | Unit | Raw (l00 g) | Raw (1cup,165g) |
|---|---|---|---|
| Water | g | 83.46 | 37.71 |
| Energy | Kcal (KJ) | 60 (250) | 99 (412) |
| Protein | g | 0.82 | 1.35 |
| Total lipid (fat) | g | 0.38 | 0.63 |
| Ash | g | 0.36 | 0.59 |
| Carbohydrate, by difference | g | 14.98 | 24.72 |

| | | | |
|---|---|---|---|
| Fiber, total dietary | g | 1.6 | 2.6 |
| Sugars, total | g | 13.66 | 22.54 |
| *Minerals* | | | |
| Calcium | mg | 11 | 18 |
| Iron | mg | 0.16 | 0.26 |
| Magnesium | mg | 10 | 16 |
| Phosphorus | mg | 14 | 23 |
| Potassium | mg | 168 | 277 |
| Sodium | mg | 1 | 2 |
| Zinc | mg | 0.09 | 0.15 |
| Copper | mg | 0.111 | 0.183 |
| Manganese | mg | 0.063 | 0.104 |
| Selenium | µg | 0.6 | 1 |
| *Vitamins* | | | |
| Vitamin C, total ascorbic acid | mg | 36.4 | 60.1 |
| Thiamin | mg | 0.028 | 0.046 |
| Riboflavin | mg | 0.038 | 0.063 |
| Niacin | mg | 0.669 | 1.104 |
| Pantothenic acid | mg | 0.197 | 0.325 |
| Vitamin 8-6 | mg | 0.119 | 0.196 |
| Folate, total | µg | 43 | 71 |
| Carotene, beta | µg | 640 | 1056 |
| Carotene, alpha | µg | 9 | 15 |
| Cryptoxanthin, beta | µg | 10 | 16 |
| Vitamin A | IU | 1082 | 1785 |
| Lycopene | µg | 3 | 5 |
| Lutein + zeaxanthin | µg | 23 | 38 |
| Vitamin E (alpha-tocopherol) | mg | 0.9 | 1.48 |
| Vitamin K (phylloquinone) | µg | 4.2 | 6.9 |

Source**:** Zafar *et al.* (2017) (Adapted from USDA 2016)

### 2.1.5 Economic Value of Mango Fruit

Food and Agriculture Organization of the United Nations Rome 2019 reported that in 2018, mango production accounted for more than half of all major tropical fruit production worldwide. The mango has risen to become the most popular tropical fruit variety in terms of production volume, thanks to its popularity in India, which accounts for an estimated 38 percent of global production (FAO, 2019). Mango is the world's fifth most consumed fruit, after citrus, banana, grapes, and apple (Requena, 2014). Malaysia is included as one of the important countries to commercialize the production of mango along other countries such as India, China, Thailand, Indonesia, Pakistan, Mexico, Brazil, and Bangladesh (Afiqah *et al.*, 2014). India is among the world's top producers with 20 million tons in 2018 of mango production making it the world's first-largest producer of mango (FAO, 2019). Most of the country's production is destined for the food industry to produce different products, like pulp, squash, nectar, drinks, mango leather, mango puree, mango fruit bars, frozen, canned mango slices, and jam (Zafar *et al*., 2017)

### 2.1.6 Varieties of Chok Anan

Chok Anan are mainly grown in Thailand's northern regions. The fruit is one of the mango cultivars that have been commercially planted in the northern region of Malaysia (Abdullah *et al.*, 2012). Due to its succulent sweet taste, the Chok Anan cultivar is known as 'honey mango' in Malaysia (Santhirasegaram *et al.*, 2013). According to the basic types of major morphological characteristics shown in figure 2, when the fruit is ripe, the skin is golden yellow, and the flesh is orange coloured. It has a pleasant fragrance and a sweet flavour (Suhaime *et al.*, 2018). Furthermore, the fruit sizes ranged from 215 $mm^3$ to 723 $mm^3$ when measured by Length x Width x Thickness. Fruit weights ranged from 120 to 380 grams, with an average of 200.9 grams. While the brix ranged from 14.5 ºBrix to 22.8 ºBrix (Abdullah *et al.*, 2018). The growth of this fruit occurs when the pollination occurs from the fruit growing from the hermaphrodite flower, while the pollination occurred when the male flower contributes pollen (Ding *et al.*, 2013).


Figure 2.1.5: Chok Anan (MA224) Mango

Source: Muda Agriculture Development Authority (MADA) (2013)

## 2.2 Fruit Leather

Fruit leather is a snack (Safaei *et al.*, 2019) that is also known as fruit bar or fruit slab. It is a dehydrated fruit-based confectionery dietary product that is commonly consumed as a healthy dessert. Fruit leathers are dried sheets of fruit pulp with a sweet taste and a soft, chewy, and flavourful, texture (Srinivas *et al.*, 2020).

### 2.2.1 Benefit of Fruit Leather

Fruit leathers produced of pulp are the most popular among customers because they include a high amount of carbs, fibre, vitamins, antioxidants, and minerals (Madusanka *et al*., 2016). It is a product that preserves all of the nutrients in the fruit for a long period. It's high in fibre, minerals, calcium, phosphorus, and iron, among other nutrients. The high nutritional content preserves one's health and helps to battle weariness and other health issues. It has a lot of fibre, which help with digestion. It helps to cleanse the digestive system while also preventing constipation and other bladder issues. It also aids in the extraction of toxins from the skin and helps improve skin health. Consumption of fruit leathers are the most effective way to lose weight as the fruits' fibre content keeps you feeling full for extended periods of time. It's also a better option if you have a sweet craving as it is capable in controlling carbohydrate and sugar consumption well automatically promotes healthy reduced weight. (Bandaru *et al.*, 2020). According to Diamante *et al.* (2014), consuming fruit leather as a source of numerous nutritional components is a cost-effective and easy value-added replacement for natural fruits.

### 2.2.2 Production of Fruit Leather

Fruit leathers are made by combining fruit puree with other ingredients such as sugar, pectin, acid, glucose syrup, pigment, and potassium metabisulphite, then dehydrating them under controlled conditions. Various drying systems including combined convective and far-infrared drying, hot air drying, microwave drying, solar drying, and sun drying have been used to make fruit leathers (Diamante *et al.*, 2014). A combination of fruits may also be used to make leather. Leathers made from a combination of fruits can also be eaten as a snack instead of boiled sweets. Fruit leathers, naturally low in fat and high in fibre and carbohydrates, and it's light enough to store and packed (Srinivas *et al.*, 2020).

According to the Food and Agriculture Organization of the United Nations (FAO) the low moisture content (15-25%), natural acidity of the fruit, and high sugar content of the fruit leathers all contributed to their long shelf life of up to 9 months if properly dried and packed (FOA, 2011). These products are economical because they reduced fruit postharvest losses and provide a convenient value-added alternative to natural fruits as a source of various nutrients (Ayalew, *et al*, 2020). As in mango fruit industry, mango is a climacteric fruit that ripens easily between 3 and 9 days after harvest that makes the value of mango decrease (Hoque *et al.*, 2017).

## 2.3 Jaggery

Jaggery is a substance made by concentrating the sweet juices of palm trees to a solid or semi-solid form. It has distinct qualities that make it preferable to white sugar in making some sweet foods. Jaggery is a substance made by boiling or processing juice extracted from sugarcane or taken from the coconut tree (Nath *et al.*, 2015). It's a natural sweetener with a sweet, wine-like smell and flavour. It has a strong scent and a delightful flavour midway between brown sugar and molasses. Jaggery is golden yellow to golden brown in colour, has a hard texture, is crystalline in structure, has a sweet flavour, and is low in moisture. It is a significant part of the diet since it is a kind of sugar that can be taken directly or used as a sweetening agent in sweet dishes. (Hirpara *et al.*, 2020).

According to Food Safety and Standards Authority of India (FSSAI), The limit of permissible quality characteristics of jaggery are moisture 7%, sucrose 70%, total sugars 90%, reducing sugars 20%, ash 4% and acid insoluble ash 0.3% (FSSAI, 2017). Jaggery is more complex than sugar since it is made up of longer sucrose and This provides users energy for a longer period of time while not harmful to the body (Kumar *et al.*, 2020). Jaggery is commonly referred to as "medicinal sugar," and it is utilised in pharmaceutical formulations. Daily use of jaggery has been linked to a longer life span in humans. Jaggery is mineral-rich and includes a significant quantity of phenol (Hirpara *et al.*, 2020).

## 2.4 Quality Analysis

Fruit leathers are preserved by having a low moisture content (15–25%), a high sugar content, and a natural acidity of the fruit. Change of colour or visual appeal, flavour, shape, texture, shelf life, and rehydration properties are the major quality parameters associated with dried fruit products, in no particular order. The raw materials, food composition, processing method, environment, packaging, and storage conditions all influence the quality of dried food items (Karki, 2011).

### 2.4.1 The Texture Analyzer (Brookfield CT3)

The Texture Analyzer (Brookfield CT3) is an instrument that works by applying a controlled deformation to a sample under given test conditions, either in compression or tension. The CT3 can measure a number of physical properties from compression and tensile data that have been shown to be strongly correlated to human sensory assessment of food such as textural (or rheological) food properties like hardness, chewiness, gumminess, tenderness, ripeness, elasticity, and adhesiveness (Brookfield, 2011).

An analytical probe is depressed into the sample at a set rate to a desired depth in this method, with a predetermined required duration between the end of the compression cycle and the beginning of the second compression cycle (Pandit et al., 2016). The tensile strength was determined using a Texture Analyzer CT3 with TexturePro CT software (Landová *et al*, 2014). The Brookfield CT3 have a software interface that has been upgraded and modernised. The Brookfield CT3 offers a greater choice of load cell options, and the instruments have a maximum load cell of 50kg. The Brookfield CT3's probe has only 0.10m travel range, which limits the sorts of tests that can be performed on this instrument (Tatelbaum, 2013).

### 2.4.2 Chroma Meter CR-400 (Konica Minolta)

According to *PR Newswire* (2014), High-performance colour measuring tools, such as the CR-400 Chroma Meter, and colour analysis software are designed to evaluate the colour and appearance of the food, beverage, and packaging products will be displayed by Konica Minolta Sensing experts. These technologies produce the data required to fix anomalies or inefficiencies in the manufacturing process early in the process, resulting in less waste and rejections. The colour of the samples is determined using a Minolta Chroma Meter CR-400 colourimeter and the CIE-Lab colour scale, with the L*a*b* (Sidor *et al.*, 2017).

According to Chroma Meter CR-400 (Konica Minolta) manual, The Chroma meter is the feature of a User Index that can configure the evaluation formula and colour calculation formula as desired. Chroma Meter CR-400 is a lightweight and high precision tool that serves as an absolute measuring tool, especially the determination of colour measurement. The Chroma meter is compatible with SpectraMagic NX software and is easy to use.

The measuring head of the chroma meter CR-400 is used to measure multiple target colours in order to get colour measurement data. To use the tool, first turn it on and check that the screen display lights are working properly. By positioning the measuring head vertically on the sample, the colour measurement must be determined in different targets. The measuring head cannot be adjusted during the colour measure phase. The colour data was shown on the screen display (Minolta, 2013).

### 2.4.3 PawKit

PawKit is a tool for measuring water activity with an accuracy of ± 0.02. Water activity with a high value is sensitive to microbial degradation, particularly for agricultural goods (Akinola, 2019).

The PawKit is a lightweight device provided with a dielectric humidity sensor that measures the activity of the sample water. Because of its capacitance sensor, the PawKit instrument has a lit, PAWKIT's accuracy (0.02 aw).

Decagon is the brand name of a PawKit manual book. The PawKit method is straightforward. PawKit is placed on a flat surface. A small sample is placed in a cup that has been carefully prepared, then stick the cup to the base of the instrument. The temperature is shown on the screen every 30 seconds after pressing the single button, and the measurement process begins. Finally, the reading is recorded 5 minutes after five deep breaths, indicating that the reading is complete (Decagon, 2001).

# CHAPTER 3

# MATERIALS AND METHODS

## 3.1 Material

### 3.1.1 Raw material

Jaggery was purchased from the local market in Jeli, Kelantan. Fresh Chok Anan mango, five kg mango were purchased from the local vendor in Jeli, Kelantan. Ripe mangoes were chosen to make fruit leather.

### 3.1.2 Equipment

The equipment used in this study were pan (Taicrocs), portable gas cooker (Milux), wooden ladle (MR DIY), weighing balance (Sartorius gold Scales 6200g Standard), electric blender (Panasonic), besen (LAVA), rectangular food tray (MR DIY premium 33.5 x 22 x 5.5 cm), fruit peeler (Barbarian head), knife (Kiwi), cutting board (Eco), zipper plastic (leadpacks), non-stick baking paper (MR DIY) and food dehydrator

(Biochef 6 tray Arizona), thermometer (Deepak Biological). The instrument used to measure the quality of mango fruit leather were Chroma Meter CR-400 (Konica Minolta), PawKit (Decagon), and texture analyzer (Brookfield CT3) were obtained from the laboratory of Universiti Malaysia Kelantan, Jeli Campus. The Instruments were showed in appendix K.

## 3.2 Method

### 3.2.1 Preparation of Mango Leather

Fresh fruit, five kg of mango were purchased from a local vendor. All fruits were cleaned using tap water and kept dry for 1 hour at room temperature. The fruit was peeled using a knife to separate the flesh and the seeds. The cut fruit was weighed according to the prescribed formulation (see Table 3.2.1). Water was added as much as 100ml along with the cut fruit and it was blended until it became a puree. The puree was put in a zipper plastic, and it was stored in a freezer with at temperature of -18°C. The shelf life of the stored puree can last for 2 weeks (Diamante *et al.*, 2014).

Table 3.2.1: Formulation F1, F2, F3 and F4 of mango leather

| Ingredient | F 1 | F 2 | F3 | F 4 |
|---|---|---|---|---|
| Fruit puree (g) | 400 | 360 | 320 | 280 |
| Jaggery (g) | 0 | 40 | 80 | 120 |
| Final weight | 400 | 400 | 400 | 400 |

The mixture of 50 ml water and jaggery was heated for 4-6 minutes. The fruit puree was added to the mixture and was heated at 80°C in 15-21 minutes to inactivate the enzyme until got a thick mixture. The mixture was cooled at room temperature in 15-20 minutes. The thick mixture was poured into a rectangular tray (33.5 x 22 x 5.5 cm) that was lined with a non-stick baking paper and spread out into a thin layer 0.2 – 0.3 cm deep. The sample underwent a drying process by using a food dehydrator. The mango leather was undergone a drying process by using Biochef 6 tray Arizona Food Dehydrator. The time taken for formulation F1, F2, F3 and F4 to fully dry was 6 hours, 9 hours, 24 hours and 36 hours, respectively in 65°C. Furthermore, the sample was cut into pieces with 5cm x 1.5 cm length. All the samples were evaluated using an instrument which are Texture Analyzer (Brookfield CT3), Chroma Meter CR-400 (Konica Minolta) and PawKit. The preparation process were illustrated in the appendix L.

### 3.2.2 Determination Physical Properties of The Mango Leather

The parameters of mango leather were evaluated based on the hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness. The texture profile analysis (TAP) brand Texture Analyzer (Brookfield CT3) equipped with a 1000 g load cell and TexturePro CT software was used to determine the parameter of mango leather. The texture analyser with probe TA 39-cylinder diameter of 2 mm speed 10.00 mm/s and with trigger load 5 g was used for the puncture test. The rectangular size of mango leather (5 cm x 1.5 cm x 0.1 cm) was held two clamps the parameter of result needs to be calculated the test of texture analysis in two cycles. At least three measurements were performed per sample, and the average was provided to record by optional software.

### 3.2.3 Colour Analysis

The colour value was measured for four formulations of mango leather using Chroma Meter CR-400 (Konica Minolta). Mango leather sample was used to analyse the colour of a rectangular shape of (37.2 x 25.5 cm). Before colour analysis, white paper was lined under mango leather. At different positions, the CR 400 chroma meter was placed vertically in the centre of the sample. The mean and standard deviation of the readings were calculated in triplicate. The value of colour determined chromatic coordinates of L*, a* and b*. A brightness L* represent the brightness in the range from 0 to 100 (black to white). Moreover, a* represent the redness – greenness specifically to describe balance in colour green to red colour. Lastly, for b* represent yellowness to blueness balance in-minus for blue to in-plus for yellow (Koike *et al.*, 2015).

### 3.2.4 Water Activity, $a_w$

Mango leather sample was used to analyse the water activity ($a_w$) of a square shape of (1.5cm x 1.5 cm x 0.1 cm). The mango leather was placed in a standard sample cup. The Pawkit sensor was uncovered by flipping back its cover and then it was inserted over a standard sample cup. The reading of water activity was shown in 5 minutes after pushing the button.

### 3.2.5 Statistical analysis

The research data were expressed in mean ± standard deviation (SD). The result obtained to differentiate the physical properties, colour, and water activity of mango leather data between two formulations were tested. The significant difference between the two mean and within-group was compared using a t-test. A value $p \leq 0.05$ was considered significant.

CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 Mango leather.

Four formulations of mango leather were shown in Figure 4.1.1, Figure 4.1.2, Figure 4.1.3, and Figure 4.1.4, which were presented according to their quality analysis of mango leather. The experiment was conducted to determine the best formulation to produce mango leather and evaluate the best formulation by analysing the qualities of mango leathers.

Figure 4.1.1: Formulation 1 (F1), 400 g mango puree + 0 g jaggery

Figure 4.1.2: Formulation 2 (F2), 360 g mango puree + 40 g jaggery

Figure 4.1.3: Formulation 3 (F3) 320 g mango puree + 80 g jaggery

Figure 4.1.4: Formulation 4 (F4), 280 g mango puree + 120 g jaggery

## 4.2 Physical Properties of Mango Leather

The hardness, chewiness, springiness, adhesiveness, cohesiveness, and gumminess of four formulations of mango leather were presented in Figure 4.2.1, Figure 4.2.2, Figure 4.2.3, Figure 4.2.4, Figure 4.2.5, and Figure 4.2.6 respectively.

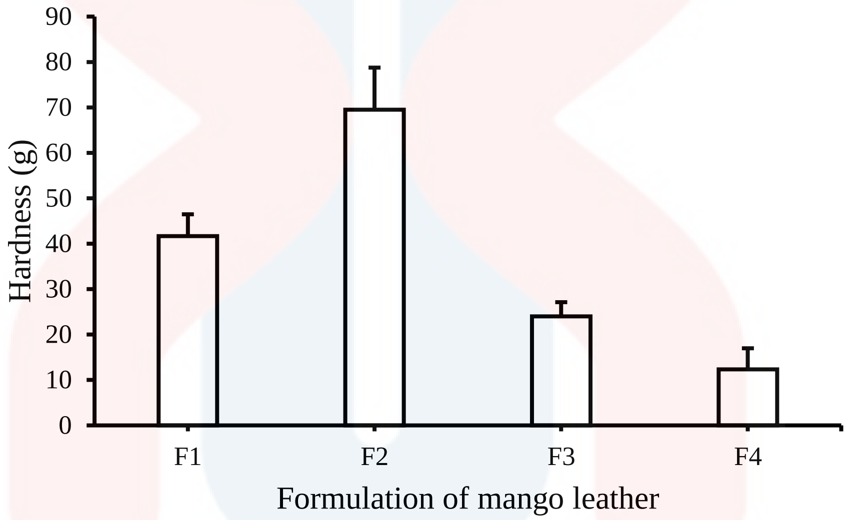


Figure 4.2.1: Hardness of mango leather for formulation F1, F2, F3 and F4.

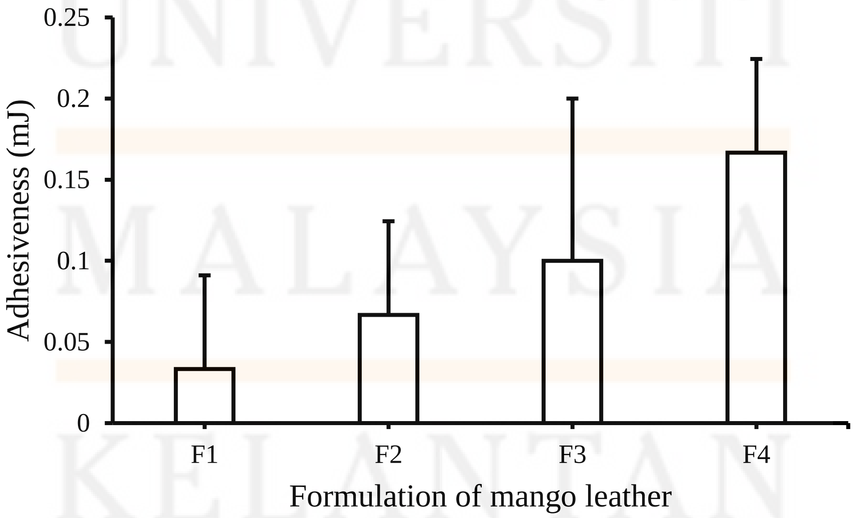


Figure 4.2.2: Adhesiveness of mango leather for formulation F1, F2, F3, and F4

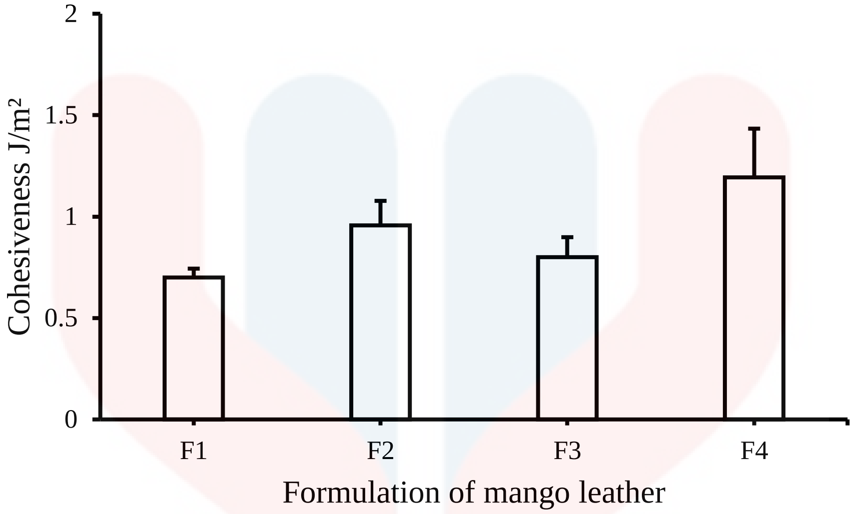


Figure 4.2.3: Cohesiveness of mango leather for formulation F1, F2, F3 and F4.

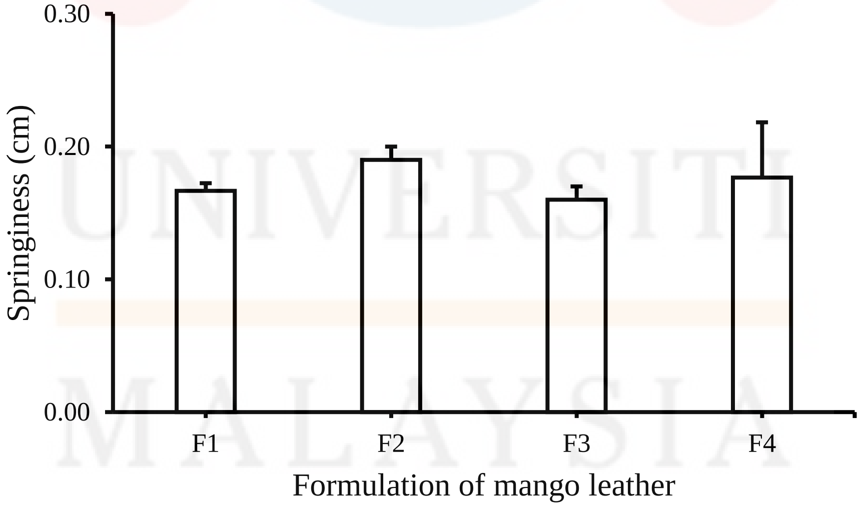


Figure 4.2.4: Springiness of mango leather for formulation F1, F2, F3, and F4.

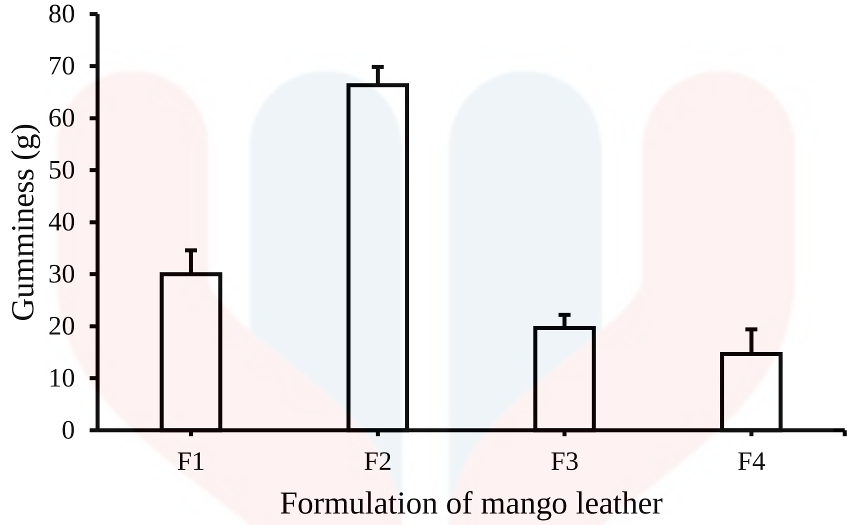


Figure 4.2.5: Gumminess of mango leather for formulation F1, F2, F3 and F4.

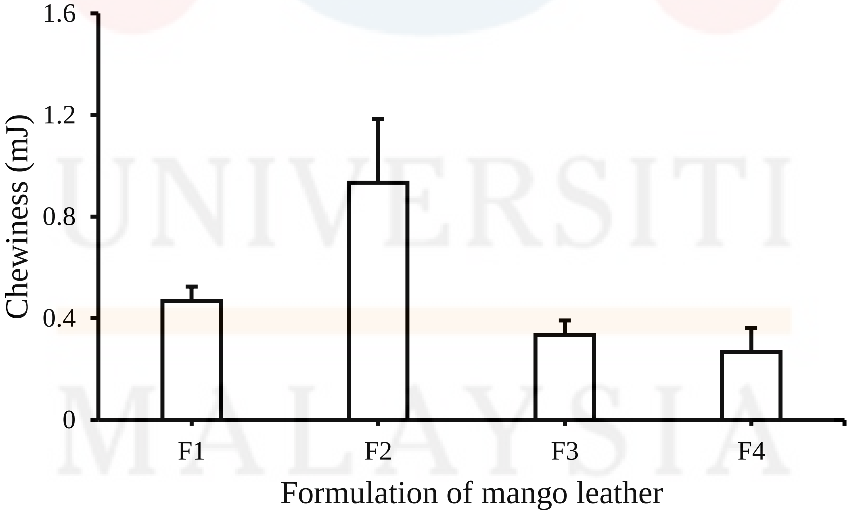


Figure 4.2.6: Chewiness of mango leather for formulation F1, F2, F3 and F4.

Based on Figure 4.2.1, the formulations F1, F2, F3, and F4 were used in this study to identify the hardness of mango leather. The results showed significant $P \leq 0.05$ hardness differences between F1 and F2, F2 and F3, and F1 and F4. There were also significant hardness differences between F2 and F3, F2 and F4, F3 and F4 with $p \leq 0.05$. Formulation of the percentage value for mango leather hardness where the comparison of F1 and F2 66.78 % was the lowest percentage value of hardness for comparing F1 among other formulations. Comparisons of hardness between F1 and F3, F1 and F4, showed an increase with values of 42.4 % and 70.41 %. In addition, the percentage value for the comparison of hardness between F2 and F3 was 65.47%, while the value of F2 and F4 showed the increased percentage value of the comparison value of other formulations which was 82.26% in the hardness study. When compared to formulations F3 and F4 the value of hardness percentage increased only 48.63%. The completed data on hardness was shown in appendix A.

In this study, based on Figure 4.2.2, the formulation F1, F2, F3 and F4 were tested to identify the adhesiveness of mango leather. From the tests that have been conducted, the results showed that the adhesiveness difference between F1 and F4 was significant $p \leq 0.05$. In contrast, the adhesiveness difference between F1 and F2, F1 and F3, F2 and F3, F2 and F3, F3 and F4 showed not significant difference $p > 0.05$. The percentage difference for mango leather adhesiveness for formulations F1 and F2, F1 and F3 showed a decrease of was 133.33 % and 233.33 %. Besides, for adhesiveness, there was the highest range of decreased values, 466.67 % for F1 and F4 formulations. In the adhesiveness analysis for F2 and F3, the percentage value of the difference was the lowest, 42.82 %. In addition, for the adhesiveness of mango leather difference between F2 and F4 has a percentage decrease of 142.86 %. Among all the formulation differences, F3 and F4 were the lower adhesiveness percentage values with a value of 70 %. The completed data on adhesiveness was shown in appendix B.

F1, F2, F3 and F4 of formulations were run in this study. As shown in Figure 4.2.3 mentioned above in this study, all the formulations were used to identify the cohesiveness of mango leather. Results of cohesiveness for F1 and F2, F1 and F4 showed that the difference between the formulations was significant $p \leq 0.05$. There was not significant difference $p > 0.05$ in F1 and F3, F2 and F3, F2 and F4, F3 and F4 for cohesiveness. For the mango leather cohesiveness test, the percentage value of the F1 and F2 formulation difference showed a decrease of 37.14 %. There was also a difference percentage decrease for of F1 and F3, where the value of cohesiveness was 14.29 %. It was the lowest value. However, F1 and F4 was a most lower percentage of cohesiveness value was 70%. In this study, only F2 and F3 were cohesiveness percentage values increased with 16.67 %. On the other hand, the percentage of cohesiveness difference between F1 and F4 decreased, 23.96 % when compared to F3 and F4, 48.75 %. The completed data on cohesiveness was shown in appendix C.

As can be seen from the Figure 4.2.4, mango leather produced F1, F2, F3 and F4 of formulations as a test for springiness. The springiness test showed not significant difference value $p > 0.05$. To study the value of the formulation percentage difference for springiness, the value for F1 and F2 was 11.76 %, which this formulation was decreased. The percentage of springiness value of the difference between F1 and F3 showed an increase of 5.88 %. F1 and F4 showed the least percentage decrease of 5.88 % while F2 and F3 were the highest percentage increase value of 15.78 % for F2, and F4 obtained a percentage increase of 5.26 % for springiness. In this study, formulations F3 and F4 was the lowest springiness percentage with the value of 12.5 % compared to all formulation comparisons. The completed data on springiness was showed in appendix D.

Figure 4.2.5 above showed F1, F2, F3 and F4 different formulations used in the gumminess study. The comparison for gumminess of F1 formulations, there was only a significant difference between F1 and F2, F1 and F4 similar with F2 and F3, F2 and F4 with $p < 0.05$. However, there were not significant difference of for gumminess F1 and F3, F3 and F4. The gumminess percentage value formulation for F1 and F2, 121.1 % was a lower value compared to the difference with other formulations. Furthermore, the values for F1 and F3 were 34.34 % while F1 and F4 were 51.1 % which was an increased percentage value of gumminess for the F1 formulation comparison. On the other hand, the gumminess difference of F2 was the highest value of the different formulations for which the values of F2 and F3 were 70.35 % compared with F2 and F4 were 77.88 %. The final formulation difference of the gumminess percentage value for F3 and F4 is 25.42 %. It was the lowest increase value. The completed data on gumminess was shown in appendix E.

This study tested F1, F2, F3, and F4 formulations. Figure 4.2.6 above showed the comparison of chewiness for F1 formulations showed that between F1 and F2, F1 and F4, there were significant $p \leq 0.05$ differences in F2 and F3, F2 and F4. Otherwise, chewiness differences were not significant at F1 and F3, F3 and F4 $p > 0.05$. In addition, the value of the formulation percentage difference between F1 and F2 chewiness showed a decrease of 97.87 %. Furthermore, the percentage values of chewiness for F1 and F3, F1 and F4 were 29.79% and 42.55%, which showed an increase for the comparison of F1 formulation. Similar to F2, the comparison between the percentage value of chewiness for F2 and F3 formulation was 64.52 %, F1 and F2 were 70.97 % which was the highest percentage increase value. Further, for the chewiness test, the percentage values of F3 and F4 increased by18.18 % only. The completed data on chewiness was shown in appendix F.

Usually, a mechanistic understanding of the observed differences in physical properties can be directly related to the results of instrumental tests (Barrett, *et al* 2010). The moisture level of the fruit leather texture is generally related to the temperature during the drying process (Okilya, *et al* 2010). In this study, the formulation F2, showed the hardness, cohesiveness, springiness, gumminess, and chewiness effects by the long drying process. According to Okilya, *et al* (2010) which claimed that a long drying process at high temperatures resulted in a hard fruit leather texture with low moisture content. Furthermore, according to the results of this study, F3 and F4 have a high jaggery content and have better physical properties than F1. This is due to the fact that sugar not only enhances flavour but also modified the texture of the product (Tireki, 2017). Moreover, the results for formulas F1, F2, F3, and F4 are acceptable in this study. Further, the results indicate the adhesiveness of formulations F1, F2, F3, and F4 is acceptable. According to Tireki, 2017 the sugar properties, such as sweetening or flavouring, solubility, viscosity, density, crystallisation, colour, and preservation, make it an important ingredient in candy manufacturing,

## 4.3 Colour Analysis of Mango Leather

Colour is important for consumer perception (Luo, *et al* 2019). Hence, during product development colour analysis is vital. In this current study, mango leather was analysed using Chroma Meter Konica Minolta CR-400 based on CIE L*a*b* analysis. The L* a* and b* values for formulation F1, F2, F3 and F4 were presented in Figure 4.3.1 and Figure 4.3.2, Figure 4.3.3 respectively.

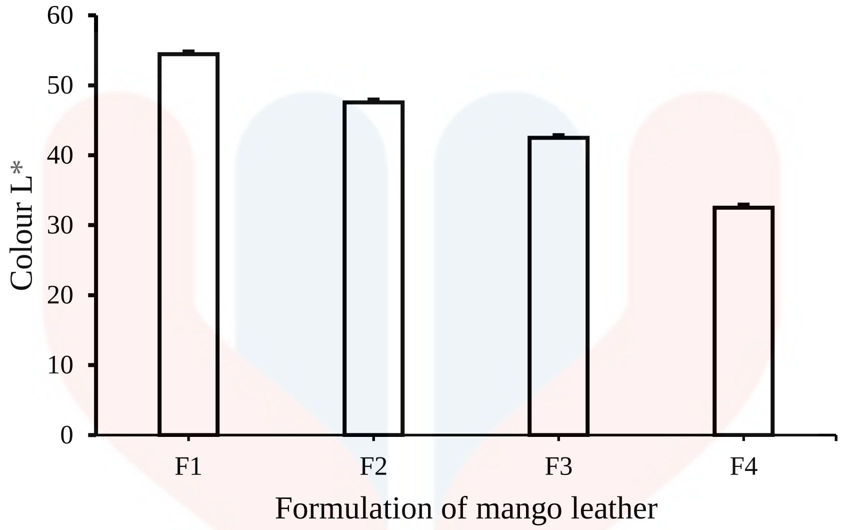


Figure 4.3.1: Colour L* of mango leather for formulation F1, F2, F3 and F4.

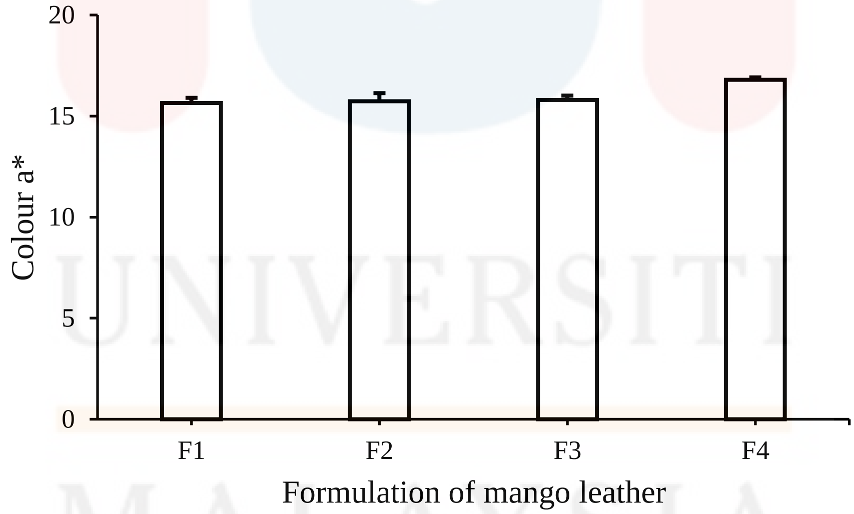


Figure 4.3.2: Colour a* of mango leather for formulation F1, F2, F3 and F4.

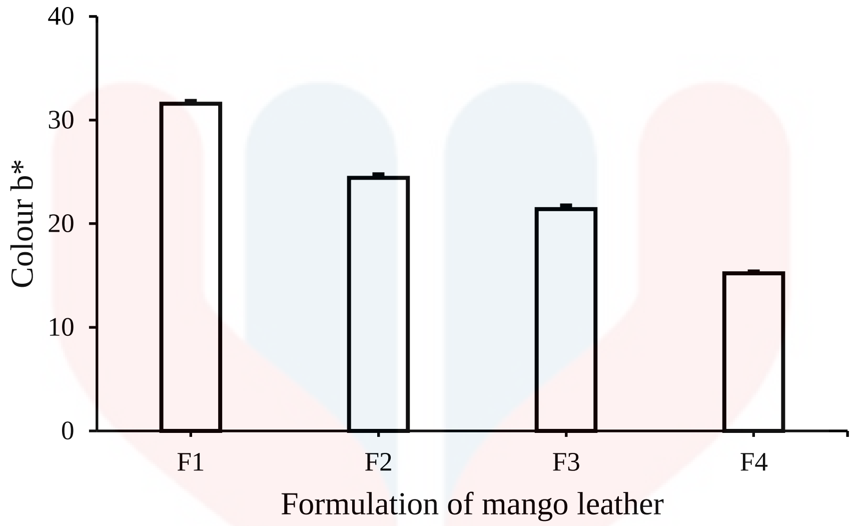


Figure 4.3.3: Colour b* of mango leather for formulation F1, F2, F3 and F4.

Colour L* analysis for mango leather was tested for F1, F2 F3 and F4 of formulations in this study. Therefore, the results of colour L* obtained were significant difference $p \leq 0.05$ on all comparisons between formulations. To study the value of formulation different for colour L* between comparisons for all formulations showed a decrease. The percentage for colour L* indicates, the increase for percentage value in F1, was 12.66%, 21.95%, and 40.3% according to the arrangement from F2, F3 and F4 formulations. Besides, for the percentages difference for F2 formulation, there was an increase of 30.65% between F2 and F4. It was the highest value for the overall formulation comparison for the colour L* test. While for contrast, F2 and F3 increased only 10.64 %. The last comparison for the colour L* test was for formulation F3 and F4, which was 23.51%. It showed an increase compared to F4 in contrast F2. The completed data on colour L* was showed in appendix G.

Based on Figure 4.8 shows the colour a* for mango leather. The colour a* for formulation mango leather F1 and F2, F1 and F3, F2 and F3 was not significant $p > 0.05$ different while it was a significant difference between F1 and F4, F2 and F4, F3 and F4 $p \leq 0.05$. The colour a* for different value percentages between F1 and F2 was 0.51 % lower than in F1, and F3 was 0.96 %. However, the percentage of mango leather formulation F1 and F4 tend to be lower, 7.28 % compared to all formulations for colour a*. The percentage of colour a* for F2 and F3 was lower than the difference of all other formulations, with a value of 0.45%. The result of colour a* obtained percentage difference for F2 and F4 was 6.74 % approximately decrease with samples F3 and F4 6.27 %. The completed data on colour a* was shown in appendix H.

Figure 4.9 above showed F1, F2, F3, and F4 were different formulations used in the colour b* study. In the comparison between colour b* for all formulations, there were significant difference determined based on the value $p \leq 0.05$. The colour b* tested showed the percentages value formulation for F1 and F2 was increased 22.67 %. The colour b* value for F1 and F3 was increased 32.2 %, while F1 and F4 was 51.84 % which was the highest value among all formulation. Even though the colour b* for F2 and F4 increase with the value of 37.71 % more than F2 and F3 with the value, 12.33 %. While the percentages of formulation colour b* value for F3 and F4 was 28.96 %, also increases. The completed data on colour b* was showed in appendix I.

The value of colour determined chromatic coordinates of L*, a* and b*. A brightness L* represent the brightness in the range from 0 to 100 (black to white). Moreover, a*represent the redness – greenness specifically to describe balance in the colour green to red colour. Lastly, b* represent yellowness to blueness balance in-minus for blue to in-plus for yellow (Ho *et al.*, 2018). During fruit bar production, a decrease in brightness indicates that a browning reaction has occurred (Salleh *et al.*, 2017). The addition of jaggery causes a change in the brightness of the colour of mango leather F2, F3 and F4 which is different from F1 (without jaggery). This is due to the caramelisation process of sugar and heat being a factor in decreasing the brightness of fruit leather (Setiaboma *et al.*, 2019).

## 4.4 Water activity ($a_w$) Analysis of Mango Leather

Water activity is very important for the shelf life of the product. In product development, the concept of water is the basis of determining food stability (Sandulachi, 2012). The water activity $a_w$ for formulation F1, F2, F3 and F4 were presented in Figure 4.4.1.

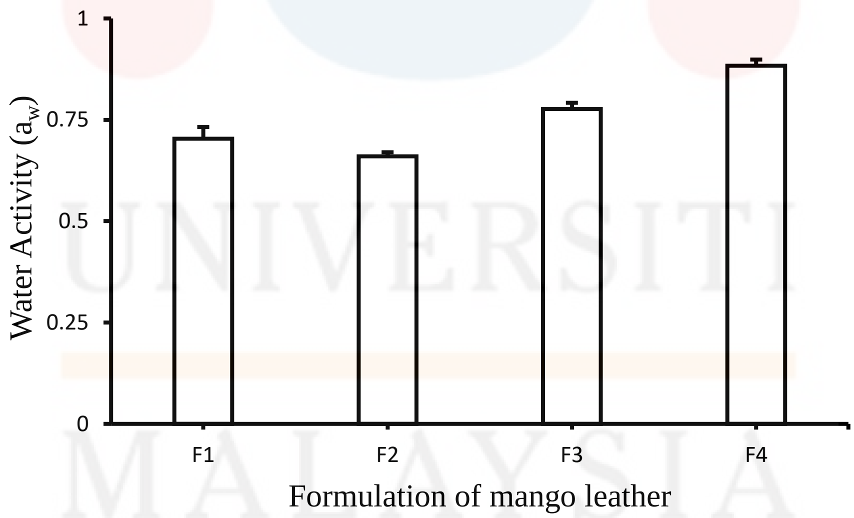


Figure 4.4.1: Water Activity ($a_w$) of mango leather of formulation F1, F2, F3 and F4.

Water activity, $a_w$ for mango leather was tested for F1, F2, F3, and F4 were different formulations. Therefore, the result water activity ($a_w$) obtained was not significant difference for comparing F1 and F2 $p > 0.05$. Although, in comparison water activity ($a_w$) between F1 and F3 and F4, there was a significant difference $p \leq 0.05$. In addition, the difference water activity, ($a_w$) between F2 and F4, similarly with F2 and F3, F3 and F4, have a significant difference $p \leq 0.05$. Mango leather has been studied the result of percentages different value for water activity, ($a_w$). The water activity ($a_w$) value for the difference between F1 and F2 was 5.71 % increase but F1 and F3,11.43 % and F1 and F4, 25.71% were decreased.  The different water activity, ($a_w$)between F2 and F4 most lower than all the differences in formulation value, 33.33%. The difference between the percentages value for water activity ($a_w$) was decreased between F2 and F3 18.18 % and F3 and F4 was 12.82 %. The completed data on water activity ($a_w$) was shown in appendix J.

The water activity for good quality fruit leather below 0.60. Water activity ($a_w$), above 0.60 causes microbes to grow rapidly and the product will be short shelf life. However, low water activity ($a_w$) produce the fruit leather became dry and tough (Diamante *et al.*, 2013). In a previous study, the high range of water activity was 0.85-0.86 resulting the development of pathogenic bacteria that may cause low storage of the product (Rahman, 2010). The study showed water activity ($a_w$) for formulations F1, F2, F3 and F4 were above 0.60. Generally, the bacteria, yeasts and moulds will not grow below water activity ($a_w$) were 0.85, 0.70 and 0.65, respectively (Karki, 2011).

# CHAPTER 5

## CONCLUSION AND RECOMMENDATION

Collectively, F3 is acceptable in terms of physical properties of hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness. However, results in terms of colour and water activity, $a_w$ needed to be improved. A high percentage of jaggery changes the colour of the finished product when compared to products that do not contain jaggery. Furthermore, because the product did not reach the range level in fruit leather manufacturing, water activity had a short shelf life.

As a recommendation, white sugar and pectin can be used as a sweetener and thickening agent to improve fruit leather texture, colour and stabilises the mass of the product can be applied in further study. Pectin can also improve the physical properties of fruit leather. Furthermore, to obtain the range of water activity $a_w$ of fruit leather, the drying process must be carefully monitored to ensure long shelf life. Besides, to strengthen the study, sensory evaluation can be conducted to access customer preferred.

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# APPENDIX A

**The completed data of Hardness**

Mean and Standard Deviation of hardness

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| MEAN | 41.67 | 69.5 | 24 | 12.33 |
| S. D | 4.8 | 9.26 | 3.12 | 4.65 |

T-test

Comparison between four formulations

| % | T-test | P-value |
|---|---|---|
| -66.78 | F1 vs F2 | 0.01175 |
| 42.4 | F1 vs F3 | 0.02806 |
| 70.41 | F1 vs F4 | 0.00943 |
| 65.47 | F2 vs F3 | 0.01167 |
| 82.26 | F2 vs F4 | 0.00225 |
| 48.63 | F3 vs F4 | 0.04747 |

A value $p \leq 0.05$ was considered significant

## APPENDIX B

**The completed data of Adhesiveness**

Mean and Standard Deviation of Adhesiveness

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| MEAN | 0.03 | 0.07 | 0.10 | 0.17 |
| S. D | 0.06 | 0.06 | 0.10 | 0.06 |

T-test

Comparison between four formulations

| % | T-test | P-value |
|---|---|---|
| -133.33 | F1 vs F2 | 0.21132 |
| -233.33 | F1 vs F3 | 0.2643 |
| -466.67 | F1 vs F4 | 0.0286 |
| -42.86 | F2 vs F3 | 0.3709 |
| -142.86 | F2 vs F4 | 0.1127 |
| -70 | F3 vs F4 | 0.21132 |

A value $p \leq 0.05$ was considered significant

## APPENDIX C

**The completed data of Cohesiveness**

Mean and Standard Deviation of Cohesiveness

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| MEAN | 0.70 | 0.96 | 0.80 | 1.19 |
| S. D | 0.04 | 0.12 | 0.10 | 0.24 |

T-test

Comparison between four formulations

| % | T-test | P-value |
|---|---|---|
| -37.14 | F1 vs F2 | 0.02813 |
| -14.29 | F1 vs F3 | 0.16442 |
| -70 | F1 vs F4 | 0.02663 |
| 16.67 | F2 vs F3 | 0.16588 |
| -23.96 | F2 vs F4 | 0.14391 |
| -48.75 | F3 vs F4 | 0.06995 |

A value $p \leq 0.05$ was considered significant

## APPENDIX D

**The completed data of Springiness**

Mean and Standard Deviation of Springiness

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| MEAN | 0.17 | 0.19 | 0.16 | 0.18 |
| S. D | 0.01 | 0.01 | 0.01 | 0.04 |

T-test

Comparison between four formulations

| % | T-test | P-value |
|---|---|---|
| -11.76 | F1 vs F2 | 0.05904 |
| 5.88 | F1 vs F3 | 0.09175 |
| -5.88 | F1 vs F4 | 0.33918 |
| 15.78 | F2 vs F3 | 0.06084 |
| 5.26 | F2 vs F4 | 0.34287 |
| -12.5 | F3 vs F4 | 0.24874 |

A value $p \leq 0.05$ was considered significant

# APPENDIX E

**The completed data of Gumminess**

Mean and Standard Deviation of Gumminess

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| MEAN | 30.00 | 66.33 | 19.67 | 14.67 |
| S. D | 4.58 | 3.51 | 2.52 | 4.73 |

T-test

Comparison between four formulations

| % | T-test | P-value |
|---|---|---|
| -121.1 | F1 vs F2 | 0.00029 |
| 34.43 | F1 vs F3 | 0.06282 |
| 51.1 | F1 vs F4 | 0.01768 |
| 70.35 | F2 vs F3 | 0.00276 |
| 77.88 | F2 vs F4 | 0.00188 |
| 25.42 | F3 vs F4 | 0.13005 |

A value $p \leq 0.05$ was considered significant

**APPENDIX F**

**The completed data of Chewiness**

Mean and Standard Deviation of Chewiness

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| MEAN | 0.47 | 0.93 | 0.33 | 0.27 |
| S. D | 0.06 | 0.25 | 0.06 | 0.09 |

T-test

Comparison between four formulations

| % | T-test | P-value |
|---|---|---|
| -97.87 | F1 vs F2 | 0.0424 |
| 29.79 | F1 vs F3 | 0.09175 |
| 42.55 | F1 vs F4 | 0.03709 |
| 64.52 | F2 vs F3 | 0.02956 |
| 70.97 | F2 vs F4 | 0.04068 |
| 18.18 | F3 vs F4 | 0.2643 |

A value $p \leq 0.05$ was considered significant

## APPENDIX G

**The completed data of Colour L***

Mean and Standard Deviation of Colour L*

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| MEAN | 54.44 | 47.55 | 42.49 | 32.50 |
| S. D | 0.38 | 0.41 | 0.38 | 0.44 |

T-test

Comparison between four formulations

| % | T-test | P-value |
|---|---|---|
| 12.66 | F1 vs F2 | 0.00121452 |
| 21.95 | F1 vs F3 | 0.00067545 |
| 40.3 | F1 vs F4 | 3.7701E-05 |
| 10.64 | F2 vs F3 | 0.00155704 |
| 31.65 | F2 vs F4 | 9.2762E-05 |
| 23.51 | F3 vs F4 | 0.00089005 |

A value $p \leq 0.05$ was considered significant

## APPENDIX H

**The completed data of Colour a***

Mean and Standard Deviation of Colour a*

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| MEAN | 15.65 | 15.73 | 15.80 | 16.79 |
| S. D | 0.25 | 0.40 | 0.22 | 0.12 |

T-test

Comparison between four formulations

| % | T-test | P-value |
|---|---|---|
| -0.51 | F1 vsF2 | 0.42016 |
| -0.96 | F1 vsF3 | 0.31722 |
| -7.28 | F1 vs F4 | 0.00784 |
| -0.45 | F2 vs F3 | 0.31351 |
| -6.74 | F2 vs F4 | 0.02705 |
| -6.27 | F3 vs F4 | 0.01043 |

A value $p \leq 0.05$ was considered significant

## APPENDIX I

**The completed data of Colour b***

Mean and Standard Deviation of Colour b*

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| MEAN | 31.58 | 24.42 | 21.41 | 15.21 |
| S. D | 0.27 | 0.34 | 0.35 | 0.18 |

T-test

Comparison between four formulations

| % | T-test | P-value |
|---|---|---|
| 22.67 | F1 vs F2 | 0.00123 |
| 32.2 | F1 vs F3 | 0.00011 |
| 51.84 | F1 vs F4 | 7.5E-06 |
| 12.33 | F2 vs F3 | 0.00742 |
| 37.71 | F2 vs F4 | 0.00052 |
| 28.96 | F3 vs F4 | 0.00041 |

A value $p \leq 0.05$ was considered significant

## APPENDIX J

**The completed data of Water activity ($a_w$)**

Mean and Standard Deviation of Water Activity, $a_w$

| | F1 | F2 | F3 | F4 |
|---|---|---|---|---|
| MEAN | 0.70 | 0.66 | 0.78 | 0.88 |
| S. D | 0.03 | 0.01 | 0.02 | 0.02 |

T-test

Comparison between four formulations

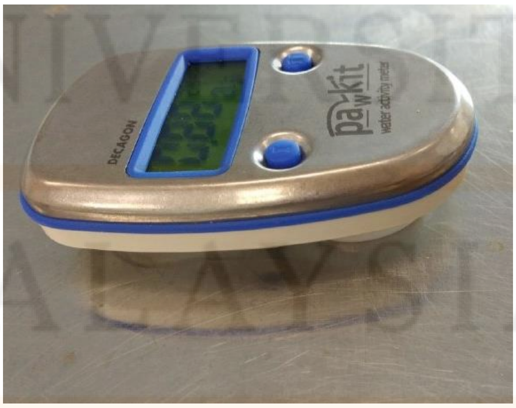
| % | T-test | P-value |
|---|---|---|
| 5.71 | F1 vs F2 | 0.06667 |
| -11.43 | F1 vs F3 | 0.03433 |
| -25.71 | F1 vs F4 | 0.00204 |
| -18.18 | F2 vs F3 | 0.00758 |
| -33.33 | F2 vs F4 | 0.00177 |
| -12.82 | F3 vs F4 | 0.00338 |

A value $p \leq 0.05$ was considered significant

**APPENDIX K**

**Illustration Instrument for Analysis Mango Leather**


Texture analyser of mango leather.




water activity $a_w$ of mango leather.

food dehydrator for drying process.


Colour analysis of mango leather.

# APPENDIX L

**Illustration for preparation of mango leather**

Cutting the mango into small pieces.

The mango was weighed using digital weighing.

Blended the mango into puree.


packed in zipped-lock plastic according based on their weight.

The main ingredient in producing the mango leather.

The used of kitchen utensils in producing mango leather.

Temperature measurement.

Mango leather before drying process.



Mango leather after drying process.