UNIVERSITI
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KELANTAN

Preparation of Pineapple Leather and Quality Analysis

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F18B0189

A thesis submitted in fulfilment of the requirements for Degree of Bachelor of Applied Science (Food Security) With Honours

Faculty of Agro Based Industry
UNIVERSITI MALAYSIA KELANTAN

2022

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 or institutions.

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I certified that the report of this final year project entitled "Preparation of Pineapple Leather and Quality Analysis" by Nurul Izzahte Ain Binti Mohd Fauzi, given matric number F18B0189 has been examined. All the corrections recommended by examiners have been done for Bachelor of Applied Science (Food Security) with Honours, Faculty Agro-Based Industry, University Malaysia Kelantan.

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ACKNOWLEDGEMENT

I would like to express my gratitude to Allah for giving me the strength to complete the thesis with His help and grace.

On this occasion, I would like to thank Universiti Malaysia Kelantan, UMK, for completing the project report at the end of this semester. This study was conducted at the Food Laboratory in the Faculty of Industry Agro-Based, FIAT at Universiti Malaysia Kelantan. The study period was completed for four months, starting October 2021 to January 2022.

I want to thank my supervisor, Dr Shamsul Bin Muhamad, for the invaluable encouragement, financial support, ideas, guidance, and advice was given to us throughout the implementation to complete this project.

Lastly, I would like to thank my family, colleagues, and all parties directly or indirectly involved in providing cooperation, assistance, support, and enthusiasm to make this final project a success.

Thank you.

Preparation of Pineapple Leather and Quality Analysis

ABSTRACT

Fruit leather is a type of dried fruit made from fresh fruit. The fruit leather in this study was produced from pineapple puree and jaggery as the main ingredient. The objective of this study was to determine the best formulation to produced pineapple leather and to determine the quality of pineapple leather in terms of physical properties, colour and water activity a_w. This study used four different formulations, F1, F2, F3 and F4 that consist of different compositions of jaggery, 0 g, 40 g, 60 g, and 120 g and different amounts of pineapple purees, which were 400 g, 360 g, 340 g, and 280 g, respectively. Brookfield CT3 Texture Analyser was used to analyse physical properties in terms of hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness. Furthermore, the colour analysis parameters L* a* b* using Konica Minolta Chroma Meter CR-400 and Paw kit for water activity analysis. The t-test was used to determine if there were significant different in comparative between the all formulations. The range of data obtained from the formulation F1, F2, F3 and F4 for the physical properties in analysis of hardness (44.83 g to 110.0 g), adhesiveness (0.03 mJ to 0.20 mJ), cohesiveness (0.65 J/m^2 to 0.82 J/m^2), springiness (0.14 cm to 0.20 cm), gumminess (28.33 g to 78.00 g), chewiness (0.40 g to 1.20 g). The lightness value (L*) for colour analysis of pineapple leather decreased as the percentage of jaggery increased. In addition, the redness value (a*) increased while the value of yellowness (b*) decreased. Moreover, the water activity analysis was in the range (0.76 to 0.91). Therefore, formulation of F3 was the satisfactory formulation based on its quality of physical properties, colour, and water activity compared with other F1, F2, and F4. In conclusion, this study proved that fruit leather produced from pineapple and jaggery warranted further research development before it can be commercialised.

Keywords: *pineapple, jaggery, physical properties, colour analysis, water activity*.

Penyediaan Kepingan Nanas Dan Analisis Kualiti

ABSTRAK

Kepingan buah ialah sejenis buah kering yang diperbuat daripada buah segar. Kepingan buah dalam kajian ini dihasilkan daripada puri nanas dan gula melaka sebagai bahan utama. Objektif kajian ini adalah untuk menentukan formulasi terbaik dalam menghasilkan kepingan nanas dan menentukan kualiti pengeluaran kepingan nanas dari segi sifat fizikal, warna dan aktiviti air. Kajian ini menggunakan empat formulasi berbeza, F1, F2, F3 dan F4 yang terdiri daripada komposisi gula melaka yang berbeza, 0 g, 40 g, 60 g, and 120 g dan jumlah puri nanas masing - masing yang berbeza, iaitu 400 g, 360 g, 340 g, dan 280 g. Penganalisis Tekstur Analyzer CT3 digunakan untuk menganalisis sifat fizikal dari segi kekerasan, kelekatan, kepaduan, keanjalan, kelekatan, dan kekenyalan. Tambahan pula, parameter untuk analisis warna L* a* b* menggunakan Chroma Meter dan Paw Kit untuk analisis aktiviti air. Ujian-t digunakan untuk menentukan sama ada terdapat perbezaan yang signifikan dalam parameter perbandingan antara semua formulasi. Julat data yang diperoleh daripada sifat fizikal dalam analisis kekerasan (44.83 g hingga 110.0 g), kelekatan (0.03 mJ hingga 0.20 mJ), kepaduan (0.65 J/m2 hingga 0.82 J/m2), keanjalan (0.14 cm hingga 0.20 cm), kelekatan (28.33 g hingga 78.00 g), kekenyalan (0.40 g hingga 1.20 g). Nilai kecerahan (L*) untuk kepingan nanas menurun apabila peratusan gula melaka meningkat bagi analisis warna. Selain itu, nilai kemerahan (a*) meningkat manakala nilai kekuningan (b*) menurun. Selain itu, analisis aktiviti air berada dalam julat (0.76 hingga 0.91 Oleh itu, formulasi F3 adalah formulasi yang memuaskan berdasarkan kualiti sifat fizikal, warna, dan aktiviti air berbanding dengan F1, F2, dan F4 yang lain. Kesimpulannya, kajian ini membuktikan bahawa kepingan buah yang dihasilkan daripada nanas dan gula melaka memerlukan penyelidikan lanjut sebelum ia boleh dikomersialkan.

Kata kunci: *nanas, gula melaka, tekstur fizikal, analisi 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
DOA	Department Of Agriculture
MPIB	Malaysia Pineapple Industry Board
USDA	United Stated Department of Agriculture
FAO	Food and Agriculture Organization

LIST OF SYMBOLS

°C	Degree Celsius
%	Percentage
+	Plus
≤	Less than
>	More

CHAPTER 1

INTRODUCTION

1.1 Research Background

Fruit leather is a chewy snack, and it is produced by dehydrating the fruit puree or a mixture of fruit juice as well as it can be considered a snack (Safaei, 2019). Fruit leathers have a sweet taste, soft texture and are chewy. It looks like flexible stripes or sheets. The final product aspect is shiny and has a leather texture (Ruiz *et al*., 2011). The pestil is an example of a product similar to fruit leather. The making of fruit leathers is from the fruit puree that has been removed with moisture that changes into leathery sheets (Yılmaz *et al*., 2017).

Pineapple, or its scientific name, *Ananas comosus*, is one of Asia's most popular tropical plants, especially in Malaysia and Thailand. The pineapple is a non-seasonal fruit (Hidayah *et, al*., 2019). The pineapple was easily deteriorated due to high production. In Malaysia, the high plantations of pineapple are in Johor, Sarawak, Sabah, Kelantan, Pulau Pinang and Selangor (DoA, 2016). According to the Department of Agriculture (DoA), pineapple production in 2015 was 272,570 metric tons and kept increasing by the year. The highest local producer of pineapple was in Johor during 2017.

Pineapple is locally developing for the local fresh fruit market. However, according to the Malaysian Pineapple Industry Board (MPIB, 2020), pineapple faced dumping at most markets and supermarkets. Local producers had to produce small products such as fresh-cut fruit of the pineapple that catered to the tastes of the locals. The losses of fruit can be minimised by making and preserving into different value-added products such as leather, juice, nectar, jam, jelly, wine, toffee, puree, pulp, sliced, and canned products (Joy *et al.* 2016). By producing fruit leathers became a value-added to economic sources of natural fruits.

1.2 Problem Statement

The pineapple is usually available in any market or supermarket. Unfortunately, the pineapple faced dumping at most markets and supermarkets. The local producer is forced to sell the pineapples at a lower price, which is not profitable. It also affects the economic source for pineapple as natural fruit. Therefore, there are many ways to maintain the increasing demand and the profit of pineapple by producing the pineapple fruit leather, which meets the consumer's need and becomes value-added to fresh fruit. It is because pineapple fruits are natural fruits with the most potential to be value-added. This study was carried out to determine the qualities of pineapple leather in terms of physical properties, colour and water activity a_w and to determine the best formulation to produce pineapple leather

1.3 Hypothesis

Ho: Fruit leather made from pineapple has the unacceptable quality of physical properties, colour, and water activity, a_w.

$H_{1:}$ Fruit leather made from pineapple has the acceptable quality of physical properties, colour, and water activity, a_w.

1.4 Objective

The objectives of this study are:

i. To determine the qualities of pineapple leather production in terms of physical properties, colour and water activity, aw.

ii. To determine the best formulation to produce fruit leather from pineapple.

1.5 Scope of the Study

The type of fruit used in this study was Josephine pineapple. Pineapple leather was formulated with different percentages of jaggery, and then the quality of fruit leather was analysed based on its physical properties, colour and water activity a_w. The Texture Analyzer (Brookfield CT3) was used to determine the parameters including hardness, springiness, cohesiveness, springiness, gumminess and chewiness. The colour of pineapple fruit leather was observes using Chroma Meter CR-400 (Konica Minolta). Lastly, the Paw kit was used to measure the water activity a_w.

1.6 Significant of Study

This study gave the people knowledge and generate the idea of producing pineapple into food products with a longer shelf life. It can be a guideline to local pineapple producers or others fruits to increase their profit. The finding of this study can generate the quality of the product from pineapple and economic value added toward tropical fruits, especially for local producers. Further research can guide people to develop a new product based on pineapple. In addition, this research can provide awareness of commercial pineapple value to increase economic outcomes. It also improves the research and development for the downstream activity of pineapple in Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 Fruit Leather

Producing fruit leather from fresh fruit is a valuable way for fruits preservation as well as for value-added to fresh fruit (Concha *et al.,* 2016). Fruit leather is widely available in countries throughout Africa, Asia and USA. It was known as fruit strips or fruit roll-ups (Roknul *et al.,* 2018). It is consumed as a snack or dessert with a healthy food-based product derived from various fruit. Almost any fruits are suitable to make fruit leather. The fruit leather is also known as restructured fruit made from mixed fruit juices, and pulp concentrates (Bandaru *et al.,* 2020).

2.1.1 Production of Fruit Leather

Various fruits had been used in leather production, such as apricot, papaya, banana, jackfruit, and orange (Torres, *et al.,* 2015). The fruit leather was produced whether pulp or juice concentrates. It can be made from a single fruit or mixed between two types of fruit. It involves the process of washing, peeling, pulping and then mixing with other ingredients and undergoing the drying process. The production of fruit leather uses heat treatment to deactivate the enzyme. In the production of fruit leather, the common additives that have been used are glucose syrups, honey and sucrose. However, it may cause stickiness problems to the product, but it can enhance its sweetness (Addai *et al.*, 2016).

An important step in fruit leather production was drying (Da *et al.*, 2020). Methods to produce fruit leathers were microwave drying, vacuum drying, hot air drying, cabinet drying, food dehydrator, solar drying and freeze-drying. Generally, fruit leather was dried at a temperature of 30 °C to 80 °C for up to 24 hours, depending on the type of drying method used. Now, the manufacture of fruit leather no longer depends on climatic conditions because of modern drying methods. The drying method had been used by spreading the pulp on the aluminium tray and dehydrating until moisture content reached 15 % to 20 %. Water and moisture content were eliminated by using many dehydrating techniques to ensure the product lasts long, reducing microbial growth and reducing the spoilage of the products. The fruit leather becomes solid and does not require refrigeration (Bandaru *et al.*, 2020). The leather can last up to 9 months if adequately dried and packaged (Fauziyah *et al.*, 2018).

2.1.2 Commercial Value of Fruit Leather

Leather became acceptable and a favourite snack for all ages. It was produced with one type of fruit or mixed with various fruits. It contains antioxidants and minerals suitable for food market (Sharma *et al.*, 2016). The consumers most widely prefer the fruit leathers made of the pulp as they consist of suitable quantities of carbohydrates, fibers, vitamins, antioxidants and minerals. The manufacture of fruit leather usually had a high pectin additive and an intense aroma compared to other processed fruits with more additional additives (Rusli *et al.,* 2019).

Fruits are processed into products to avoid losses at post-harvest. Most short harvesting fruits are easy to deteriorate even when stored in cold conditions. Therefore, making fruit leather from fresh fruit is the best way to avoid fruit deterioration quickly and the benefits for economical production of fruit leather. Primarily the leathers were prepared from the left-over ripe fruits. Thus, the fruit can be produced into the leather to ensure a long-lasting fruit product (Ewekeye *et al.*, 2013).

According to FAO, 2016 fruit leather was among the sweetest, gummy texture and soft fruit processing products. Relatively, fruit leathers are a low-price product, healthy, practical and easy to eat (Fauziyah *et al.,* 2020). The development of fruit leather contributes to the quality of tropical fruit-based products and value-added to Malaysian products. Fruit leather had been widely marketed mainly in Europe at the international market level, such as Apricot leather, Grape leather and Kiwi leathers (Rusli *et al.,* 2019).

2.1.3 Quality Analysis of Fruit Leather

Generally, the main parameters associated with dried fruit products are shape, texture, flavour, colour, shelf life, retention of nutrients, microbial load, rehydration properties, contaminants, water activity, chemical stability, and porosity (Ghimire *et al.*, 2016). The product of fruit leather can mostly be defined as texture properties in terms of taste, texture, colour, flexibility, and viscosity (Saidi *et al.*, 2020). High-temperature factors and extended drying times produce a hard fruit leather texture. In addition, differences in fruit leather texture were also influenced by fruit type as it has different water absorption rates and different fruit protein content. Furthermore, the addition of sugar in the production of fruit leather was also one of the causes of changes in texture, and sugar plays a role in improving the taste of fruit leather (Okilya *et al.*, 2010).

2.1.3.1 Texture Analyzer (Brookfield CT3)

Texture Analyzer brand Brookfield CT3 manual book stated that the Texture Analyzer was used to measure the properties of the food product related to sensory properties detected by humans. Moreover, Brookfield CT3 Texture Analyzer is a third-generation texture testing tool. The purpose of this tool is to characterise the sample as a human sensory substitute for texture analysis.

It had been studied for over fifty years to develop the instrumental properties that can obtain the result by the calculated test of texture analysis. Texture Analyzer consists of the controlled forces for product and then the force was developed by recording the response for time and deformation. This instrument was specific to the food industry. Texture Analyzer consists of the optional software and can easily create graphs and a custom report. The parameter that can be measured by Texture Analyzer are hardness, gel strength, cohesiveness, adhesiveness, firmness, consistency, ripeness, burst strength, elasticity, pliability, breaking point and fracture ability (Brookfield CT 3, 2011).

Apart from that, a study by Saidi *et al.* 2020 was used the same instrument as in this study to measure the quality of Mixed vegetable-fruit leathers. The physical properties were measured in term of hardness, cohesiveness, adhesiveness, springiness, chewiness, and gumminess. The Brookfield Texture Analyzer CT3 was equipped with a 1000 g load cell in this study. The sample of Mixed vegetable-fruit leathers were prepared in size, 3 cm x 3 cm. It was pressed twice using a TA-9 type probe to an 8.0 mm target. The speed set when analysing the instrument was 10 mm/s, while the load weight was 6.8 g. Three measurements were done per sample to measure the quality of Mixed vegetable-fruit leathers.

2.1.3.2 Chroma Meter CR-400 (Konica Minolta)

According to Chroma Meter CR-400 brand, Konica Minolta manual book Chroma Meter CR-400 is a lightweight and high precision tool that serves as an absolute measuring tool, especially the determination of colour measurement.

Moreover, Chroma Meter CR-400 is an instrument designed to measure colour in the minimal colour variation condition. It provides standard or customised evaluation formulas that can help the user control the quality of the colour with a reliable colourimeter. This instrument accurately identified the characteristic of the colour and the difference between the object. The model of CR-400 can be applied to obtain the optional data processor. It provides the result on-site or Spectra Magic NX software to record the measurement and comprehensive colour analysis.

The chroma meter CR-400 was used the measuring head to measure different target colours to obtain colour measurement data. The use of the tool begins by pressing the on button and making sure the Screen display lights work correctly. The determination of the colour measurement must be in the different targets by placing the measuring head vertically on the sample. During the colour measurement process, the measuring head cannot be moved. The colour data display appears on the screen display (Minolta, 2013).

2.1.3.3 Paw kit

According to Paw kit manual book brand Decagon, Paw kit is a lightweight device. It is equipped with a dielectric humidity sensor to measure sample water activity. The paw kit instrument has its lit, PAW KIT's accuracy (± 0.02 a_w) due to its capacitance sensor. It requires a small sample size to obtain water activity readings. The risk of not getting an accurate reading if the sample size is too large.

The method used for Paw Kit was very simple. Firstly, Paw kit was placed on a flat surface. A small-sized sample is placed in a properly prepared cup. After that, stick the cup to the bottom of the instrument. Press a single button, and the measurement process starts when the screen displays the temperature every 30 seconds. Lastly, the reading was taken in 5 minutes after the beep five times, indicating the reading was over (Decagon, 2001).

On the other hand, Paw Kit is known as a device to measure water activity a_w. The important role of Paw Kit can determine the water content between the percentage of wet mass or dry mass of the sample. This is because Paw Kit can indicate a material either has a high or low moisture content (Ramnanansingh *et al.*, 2012).

2.2 Jaggery

Jaggery is made from a concentration of sugarcane juice. It was a natural sweetener. Jaggery was a healthy sweetener because it contains all the minerals and vitamins in sugarcane juice. Thus, jaggery was easily digested and provides energy for a long time (Nath *et al.*, 2015). In addition, there are two types of jaggery produced, namely light golden and dark brown. However, jaggery that had a bright golden-brown colour was the high demand in the market (Selvi *et al*., 2021). The variety of products produced using jaggery provides innovative added-value products. This encourages the community to minimise the consumption of white sugar (Vengaiah *et al*., 2017).

Besides, the nutrient content found in jaggery was obtained naturally from sugarcane. Hence, it is considered healthier than white sugar. Among the nutrient contents in jaggery are minerals, fructose and protein (Mohan *et al*., 2020). Jaggery was prepared naturally. The proximate composition contained in jaggery was ash (3.25 %), moisture (8.97 %) and total sugar (73.87 %). Therefore, jaggery can be an alternative to sucrose and is a nutritious sweetener (Vengaiah *et al*., 2017).

2.3 *Ananas comosus* (Pineapple)

2.3.1 Taxonomy and Origin

The general botanical name for pineapple is *Ananas comosus.* It can be classified as a tropical, herbaceous and monocot perennial plant. Pineapple fruits are also grown commercially in specific places such as South Africa and Kenya. Pineapple is the third most crucial economic plant after banana and citrus. Pineapple fruits are suitable for cultivating in tropical and subtropical regions because of the climate and rainfall distribution (Shamsudin *et al*., 2020). Statista, 2020 reported the top five worldwide pineapple producers like Costa Rica, Philippines, Brazil, Thailand, and India during 2017. The proper cultivation and excellent agricultural practices can produce a good taste and aromatic pineapple fruits.

Figure 2.3.1: *Ananas comosus* (pineapple).

Source: Shamsudin *et al*., (2020)

2.3.2 Morphology

Figure 2.3.2 below shows the pineapple structure have the crown, stem, peduncle, leaves, multiple fruits, shoots and roots. The size of plant growth for pineapple ranges between 1 to 2 m tall and wide. Meanwhile, the pineapple plant has spiral leaves and flowers. The pineapple also has a stem at the centre with a length between 25 to 50 cm. Therefore, identifying a mature pineapple plant by placing the leaves seems like a sword-shaped in quantities of around 60 to 80 leaves (Wali., 2019).

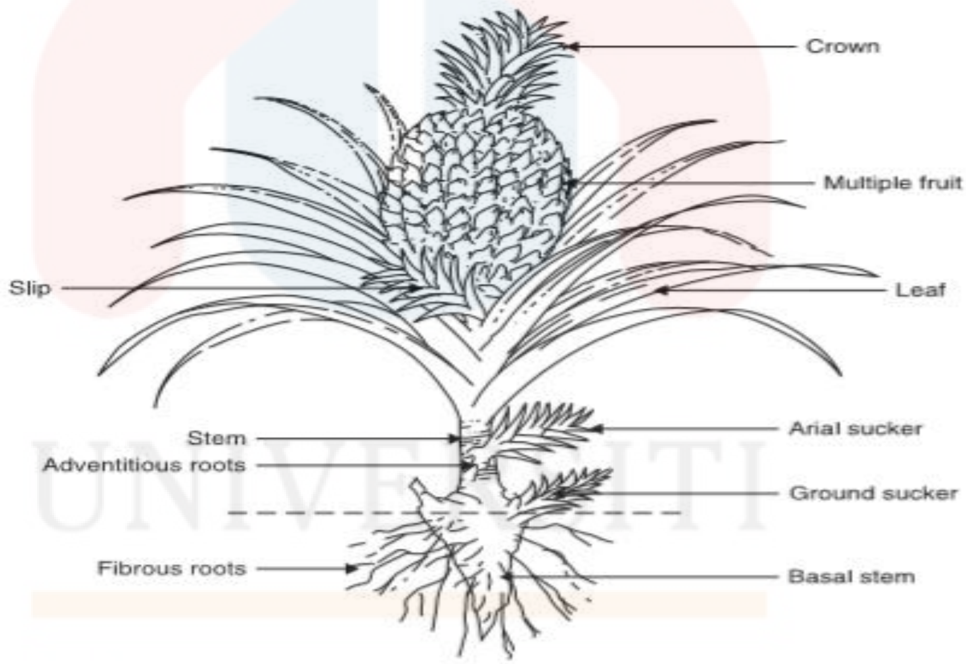

Figure 2.3.2: Morphology structure of pineapple fruit

Source: Hassan *et al.,* (2011)

2.3.3 Nutritional Value

Table 2.3.3 below shows the nutritional value for 100 g of pineapple. The pineapple is rich in essential nutrients such as calcium, potassium, copper, vitamin C, folate, fibre, glycans, and other vital elements. The composition of pineapple contains a low amount of fat and sodium while taking in a high amount of carbohydrates (Hossain *et al.*, 2015). The table also shows the overall composition with the water as a significant component, while the solid portion containing pineapple indicates 85 % for carbohydrate, sucrose, glucose and fructose (USDA., 2015).

Table 2.3.3: Nutritional value of pineapple

Nutrient	**Value per 100g**
Water	88 g
Energy	50 Kcal
Energy	209 KJ
Protein	0.54 g
Total lipid	0.12 g
Carbohydrate	13.12 g
Total sugars	9.85 g
Calcium	13 mg
Potassium	109 mg
Magnesium	12 mg
Phosphorus	8 mg
Vitamin C	47.8 mg
Niacin	0.5 mg
Pantothenic acid	0.213 mg

Source: US Department of Agriculture, USDA (2015)

2.3.4 Varieties of Pineapples

According to the Malaysian Pineapple Industry Board (MPIB), there are nine varieties of pineapple cultivation in Malaysia which are N36, Masapine, Moris, Josaphine, Morris Gajah, Sarawak, Yankee, Gandul and most recently, MD2 (MPIB., 2020). However, the widely grown in Malaysia are Yankee, N36, MD2, Morris, Josephine, Gandul and Morris Gajah. This study chooses the variety of Josephine pineapple that was considered based on the availability and accessibility of the cultivar.

Figure 2.3.4 below show Josephine pineapple. The shape of Josephine pineapple was cylindrical with the weight in about 1.3 kg. The colour of unmature fruit was dark green shade and it turn to reddish orange when ripe. It consists the dry and crunchy flesh which it contains 16 until 17-degree brix of sugar level. The acid level for Josephine Pineapple is moderate and high quality (Ahmad *et al*., 2018).

Figure 2.3.4: Josephine Pineapple

Source: Ahmad *et.al*. (2018)

2.3.5 Emerging Product and Potential Market of Pineapple

The economic and commercial importance of the pineapple has promoted further investigation in biotechnology to develop techniques to generate the growth of pineapple production. The pineapple is one of the most popular tropical fruits in the world. It is a tradable crop that is very reasonable to increase income and provides over 24.8 million tonnes based on 2013 data. The pineapple is widely used for human consumption, such as fruit and juice to make jam. Other than that, the main uses of pineapple are tenderising various types of meat because it contains some enzymes that are very beneficial in meat production. In general, the production of pineapple has one extended and varied market (Asante-Poku *et al.*, 2016). Therefore, the use of pineapple to manufacture the product is well worth it to be commercialised. It can also be the value-added for downstream products.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Raw Materials

In the preparation of pineapple leather, the final product must have a good quality of raw materials. Jaggery was purchased from the local market in Jeli, Kelantan. 5 kg of pineapples were purchased from the local vendor in Jeli, Kelantan. The ripe pineapple was chosen based on the quality to make fruit leather.

3.1.2 Equipment

Cooking utensils were provided by the food laboratory, FIAT in University Malaysia Kelantan, UMK. The equipment used to prepare the pineapple puree were a knife (Kiwi), cutting board (Eco), zipper-lock plastic bag (Lead packs), thermometer (Deepak Biological) and besen (LAVA). Furthermore, other equipment includes the blender (Panasonic), weighing balance (Sartorius Gold Scales 6200g Standard), pan (Thai crocs), portable gas cooker (Milux) for blending, mixing and heating the pineapple puree and jaggery, whereas to pour the thick mixture was using rectangular tray (33.5 cm x 22 cm x 5.5 cm), non-stick baking paper (Mr. DIY) and for drying the pineapple leather was using a food dehydrator (Bio Chef Six Tray Arizona). The instruments used to measure the quality of pineapple fruit leather were Texture Analyzer (Brookfield CT3, USA), Chroma Meter CR-400 (Konica Minolta, Japan) and Paw kit (Decagon, USA). The illustrations of equipment are shown in Appendix K.

3.2 Methods

3.2.1 Preparation of Pineapple Leather

5 kg fresh of pineapple were manually removed the peel using a knife to obtain fruit flesh. All fruit was cleaned using tap water to remove dirt, and it was kept to dry for 1 hour at room temperature and then blended using a blender to obtain juice.

The cut fruit was weighed based on formulation as shown as in table 3.2.1. Water was added 100 ml along with the fruit and blended until it became puree. The puree was put into a zipper-lock plastic and stored in a freezer with a temperature of -18 °C.

The jaggery was melted by adding 50 ml water to medium heat, and the pineapple puree was added. It was heated at 80 °C until a thick mixture in 15 to 30 minutes. The mixture was cooled to room temperature in around 15 to 20 minutes. The thick mixture was poured into a rectangular tray (33.5 cm x 22 cm x 5.5 cm), and it was lined with non-stick baking paper and spread out into a thin layer 0.2 cm to 0.3 cm deep. The mixture was dried by using a food dehydrator. The time taken for formulations F1, F2, F3 and F4 fully dry was 6 hours, 10 hours, 24 hours and 36 hours, respectively, in 65°C.

Further, it was cut into pieces with 5 cm x 1.5 cm length. All four formulations, F1, F2, F3 and F4 of pineapple leather, were evaluated the physical properties, colour and water activity by using the instruments Texture Analyzer, Chroma Meter CR-400 and Paw kit, respectively. The illustration for the preparation of pineapple leather is shown in Appendix L.

Table 3.2.1 Pineapple leather formulation

Ingredient	Formulation 1	Formulation 2	Formulation 3	Formulation 4
Pineapple Puree (g)	400	360	320	280
Jaggery (g)	0	40	80	120
Total weight (g)	400	400	400	400

3.2.2 Determination Physical Properties of the Pineapple Leather

The quality parameter of pineapple leather was evaluated based on the hardness, gumminess, cohesiveness, adhesive, chewiness and springiness. It was measured by Texture Analyzer (Brookfield CT3). The Texture Analyzer (Brookfield, CT3, USA) equipped with a 1000 g load cell and Texture Pro CT3 software was used to determine the parameter of pineapple leather. The Texture Analyzer was used the probe TA 39-cylinder diameter of 2 mm and speed 10.00 mm/s for the puncture test. The sample size to determine the physical properties was the rectangular shape with the measuring of pineapple leather (5 cm x 1.5 cm x 0.1 cm). It was held by two clamps. The parameter result needs to be calculated test of texture analysis in two cycles. At least three measurements were done per sample, and the average was provided to record by optional software.

3.2.5 Determination for colour analysis of the pineapple leather

The determination of colour attributes of pineapple leather by a colour meter. Colour was measured for pineapple leather and carried out by Chroma Meter CR-400 (Konica Minolta). The sample size of pineapple leather was used to analyse the colour of a rectangular shape measuring (37.2 cm x 25.5 cm). The white paper was lined under pineapple leather before colour analysis. The Chroma Meter CR-400 was placed vertically in the centre of the sample at different places. Readings were measured in triplicate. The value of colour was determined by chromatic coordinates of L*, a* and b*.

Chroma meter gave the L* (lightness), a* (redness) and b* (blueness) reading in measuring the colour intensity of the pineapple leather.

3.2.6 Determination for Water Activity, a_w of the Pineapple Leather

The sample size of pineapple leather was used to analyse the water activity in a square shape measuring (1.5 cm x 1.5 cm x 0.1 cm). The reading was obtained by placed the pineapple leather on the top of a standard sample cup and flipping back the sensor cover. The water activity of pineapple leather reading appeared in 5 minutes. The data was measured in triplicate.

3.2.7 Statistical Analysis

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

CHAPTER 4

RESULT AND DISCUSSION

4.1 Pineapple Leather

The formulation of pineapple leather consists of F1, F2, F3, and F4. The experiment was conducted to determine the best formulation for producing pineapple leather and evaluate the best formulation by analysing the qualities of pineapple leathers. Four formulations of pineapple leather are shown in Figure 4.1.1, Figure 4.1.2, Figure 4.1.3 and Figure 4.1.4.

Figure 4.1.1: Formulation 1 (F1), 400 g of pineapple puree + 0 g of jaggery.

Figure 4.1.2: Formulation 2 (F2), 360 g of pineapple puree + 40 g of jaggery.

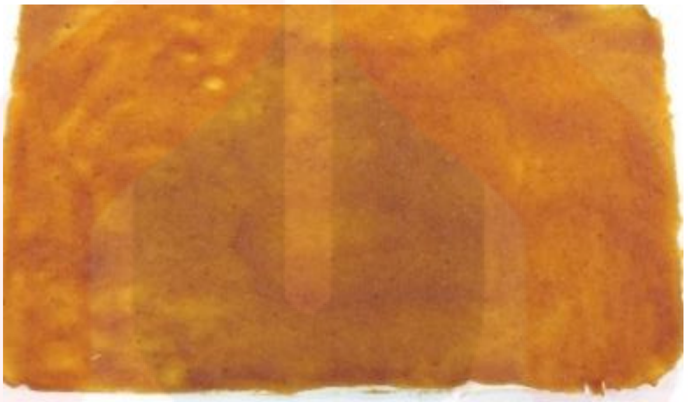

Figure 4.1.3: Formulation 3 (F3), 320 g of pineapple puree + 80 g of jaggery.

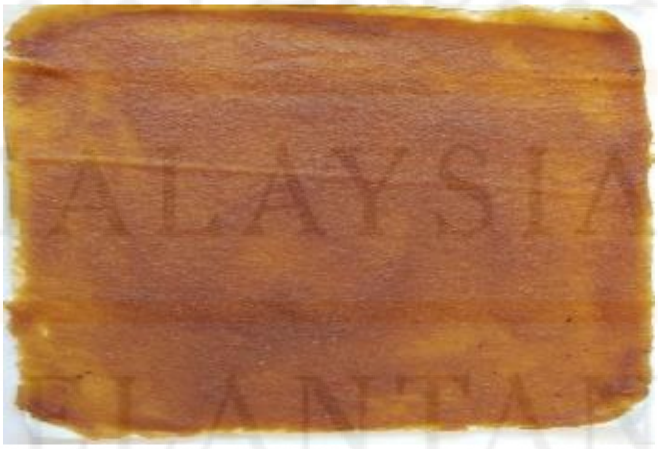

Figure 4.1.3: Formulation 4 (F4), 280 g of pineapple puree + 120 g of jaggery.

4.2 Physical Properties of Pineapple Leathers.

The quality characteristics from instrumental evaluations were hardness, adhesiveness, cohesiveness, springiness, gumminess and chewiness. The results obtained 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.

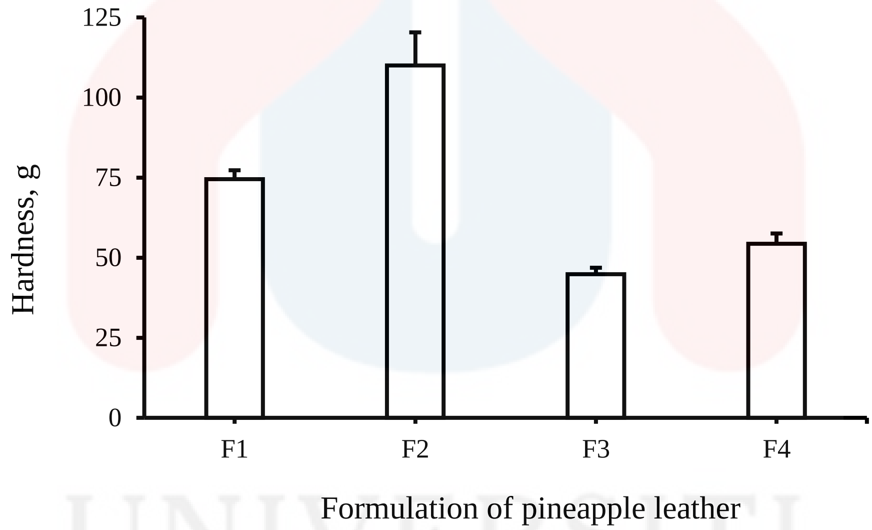

Figure 4.2.1: Hardness of pineapple leather for formulation F1, F2, F3 and F4

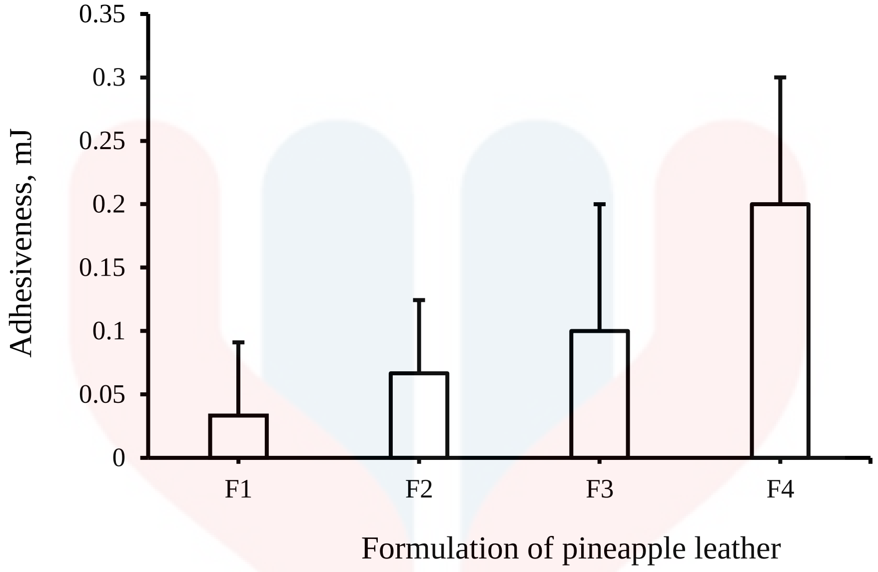

Figure 4.2.2: Adhesiveness of pineapple leather for formulation F1, F2, F3 and F4

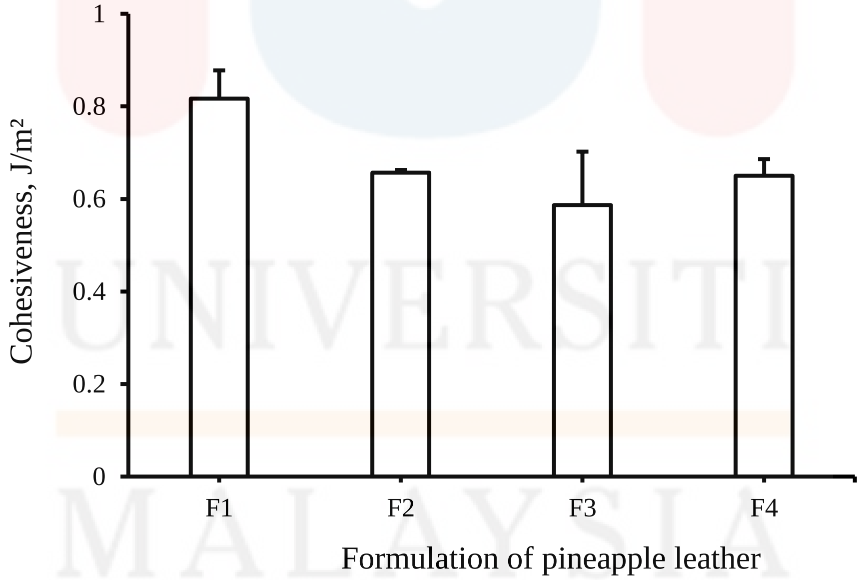

Figure 4.2.3: Cohesiveness of pineapple leather for formulation F1, F2, F3 and F4

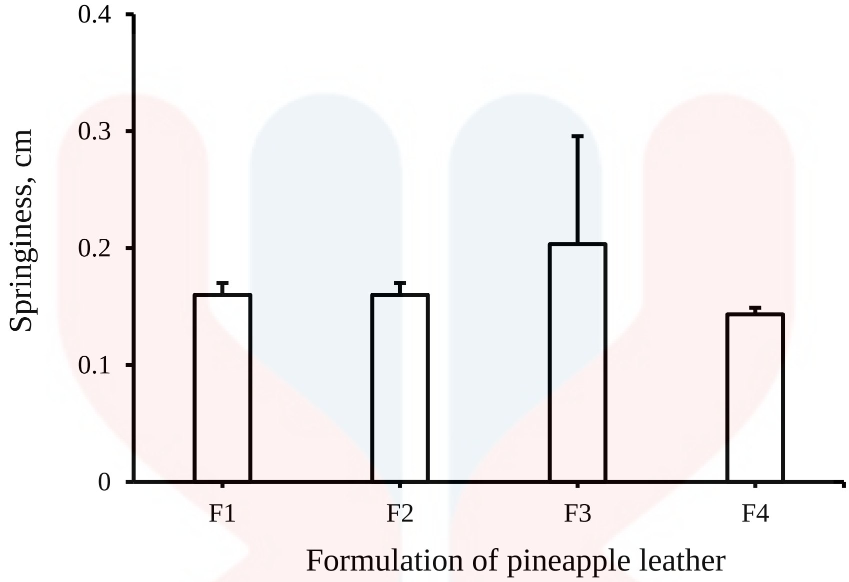

Figure 4.1.4: Springiness of pineapple leather for formulation F1, F2, F3 and F4.

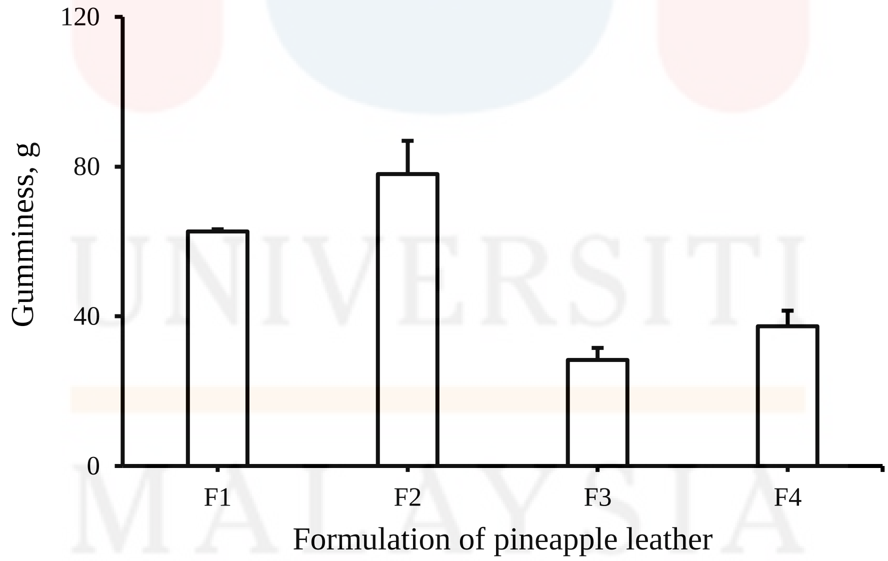

Figure 4.2.5: Gumminess of pineapple leather for formulation F1, F2, F3 and F4

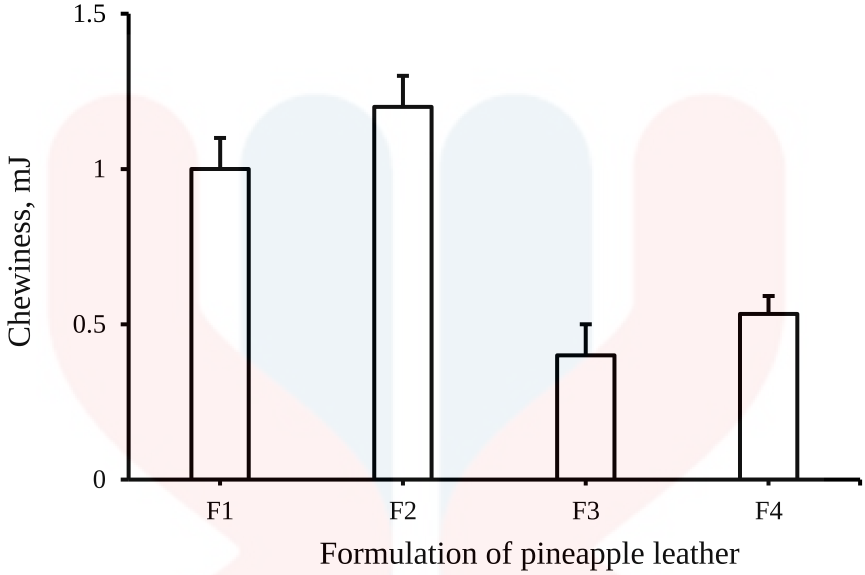

Figure 4.2.6: Chewiness of pineapple leather for formulation F1, F2, F3 and F4

Based on Figure 4.2.1, the formulations F1, F2, F3 and F4 identified the hardness of pineapple fruit leather. The hardness difference between of F1 and F2, F1 and F3, F1 and F4 were significant with $p \leq 0.05$. There were also significant differences hardness between for formulation F2 and F3, F2 and F4, F3 and F4 $p \leq 0.05$. The difference value between F1 and F2 is 47.65 % was lower than all formulations. F1 and F3, F1 and F4 with 39.83 % and 30.2 %, respectively, also decreased, showing minor differences. However, the percentage of hardness difference between F2 and F3, 59.23 %, was higher than F2 and F4, with 50.61 % and other formulations. The difference hardness in value between F3 and F4 was 21.19 %. It showed the value of decrease between each formulation. The completed data on hardness is showed in Appendix A.

Based on Figure 4.1.2, comparison adhesiveness between F1 and F2, F1 and F3, F1 and F4 were not significant with p > 0.05 likewise, the adhesiveness for F2 and F3, F2 and F4, F3 and F4 also had not significant difference between p > 0.05. Differential value adhesiveness between F1 and F2 was 133.33 % lower than F1 and F3, 233.33 %, respectively, while the adhesiveness between F1 and F4 became the higher formulations differences percentage with the value, 566.67 %. However, for the adhesiveness of pineapple leather, the percentage difference between F2 and F3, 42.86 %, was increased than all formulations. The result adhesiveness of difference values for F2 and F4, with 130.00 % compared with F3 and F4 being 100.00 %, indicating a lower value of differentiating between formulation. The completed data on adhesiveness is showed in Appendix B.

As shown on Figure 4.1.3, the cohesiveness of pineapple leather was a significant difference between F1 and F2, F1 and F3, F1 and F4. However, cohesiveness between F2 and F3 and F2 and F4 formulations were not significant with p > 0.05. Comparison cohesiveness between F1 and F2, F1 and F2, F1 and F3 was 19.28 %, 28.05 % and 20.73 %, where the F1 and F3 formulations were increased among all difference formulations. In addition, the cohesiveness of difference value between F2 and F3 was 10.61 %. Moreover, F2 and F4, which was 1.52 %, show a decrease value, but the percentage cohesiveness for F3 and F4 was 10.17 %. Therefore, it showed the lowest differences in the study of cohesiveness comparing differences for other formulations. The completed data on cohesiveness is shown in Appendix C.

Based on Figure 4.1.4 shows the springiness of pineapple leather. The springiness study showed no significant difference between F1 and F2, F1 and F3, F1 and F4, including F2 and F3 formulations where it was also not significant with $p > 0.05$. For this springiness test, only formulations F2 and F4 were significant with the value $p \leq 0.05$ compared to other formulations. In addition, F3 and F4 were also not significant with the value of $p > 0.05$. The springiness test difference between F1 and F2 was 0 %, so there was no difference between each formulation. However, F1 and F2, F1 and F3 were 25 % and 12.5 %. Therefore, there was a decrease in terms of differences between formulations. On the other hand, there was a similar decrease in the value difference between F2 and F3 and F2 and F4, 25 % and 12.5 %, respectively. It indicates that there was a similarity of values for the four formulations when compared to other formulations. However, the springiness result showed that the highest difference value based on formulation percentage comparison for springiness between F3 and F4, 30 %. The completed data on springiness is shown in Appendix D.

Figure 4.1.5 shows the gumminess analysis of pineapple leather. Analysis obtained for different values between F1 and F2, F1 and F3 include F1 and F4 for the gumminess of pineapple leather that had a significant difference. Furthermore, the gumminess of F2 and F3, F2 and F4 were significant with the value of $p \leq 0.05$. However, the gumminess of F3 and F4 were not significantly different from other formulations after determining the value $p > 0.05$. The formulation difference for the gumminess test was lower between F1 and F2, with a value of 24.46 %. However, F1 and F3 had an increase comparing of gumminess for difference value of formulation with 54.79 % than F1 and F4 with only an increase of 40.43 %. Conversely, the value of the difference between formulations F2 and F3 showed a major increase of 63.68 % for gumminess test. Thus, it was a high difference value between other formulations for gumminess, and even when compared to F2 and F4, the value decreases by 52.14 %. However, the difference between the values of gumminess for F3 and F4 was the lowest among all formulas, which was 31.77 %. The completed data on gumminess is showed in Appendix E.

Based on Figure 4.6, a total of four different formulations, F1, F2, F3 and F4, to study the chewiness of pineapple leather. The difference between chewiness analysis for F1 and F2 was not significant with the value of $p > 0.05$. However, the chewiness for F1 and F3 and the comparison between F1 and F4 were significant when the value $p \leq 0.05$ was similar to F2 and F3. Besides, the chewiness of F3 and F4 showed a not significant difference with $p > 0.05$. The percentage value formulation difference for the chewiness test between F1 and F2 was 20 %, where it showed a decrease compared to F1 and F3 and F1 and F4, 60 % and 47 %, respectively. In studying the difference value in chewiness analysis, there was the highest value of 66.67 % for the difference of F2 and F3 formulations. Hence, it becomes the most comparative value compared to other formulations. In addition, the value of the percentage difference of chewiness for F2 and F4 was 55.67 %. The percentage difference in value for F3 and F4 for the chewiness test of pineapple leather was a slight decrease of 32.5 %. The completed data on chewiness is showed in Appendix F.

Typically, physical properties study the mechanistic understanding of observed differences from direct instrumental test results (Barret *et al.,* 2010). In general, the temperature during the drying process was associated with the moisture content of the fruit leather texture (Okilya *et al.,* 2010). This study, F2, showed that the long drying process influenced hardness, cohesiveness, springiness, gumminess, and chewiness. According to Okilya, 2010, a long drying process and high temperatures will produce a hard fruit leather texture and low moisture content. In addition, the results obtained through this study, F3 and F4 have a high jaggery content where the physical properties obtained are better than F1. Sugar acts as a flavour enhancer and modifies the product's texture (Tireki., 2017). In addition, this study shows the results for formulations F1, F2, F3 and F4 have acceptable adhesiveness. According to Tireki, 2017, the properties of sugar such as sweetening or flavouring, solubility, viscosity, density, crystallisation, colour and preserving make it an important ingredient in candy manufacturing.

4.3 Colour Analysis of Pineapple Leathers.

Colour is important for consumer perception (Tesfay et al. 2018). Hence, during product development, colour analysis is vital. This study analysed pineapple leathers 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, Figure 4.3.2 and Figure 4.3.3, respectively.

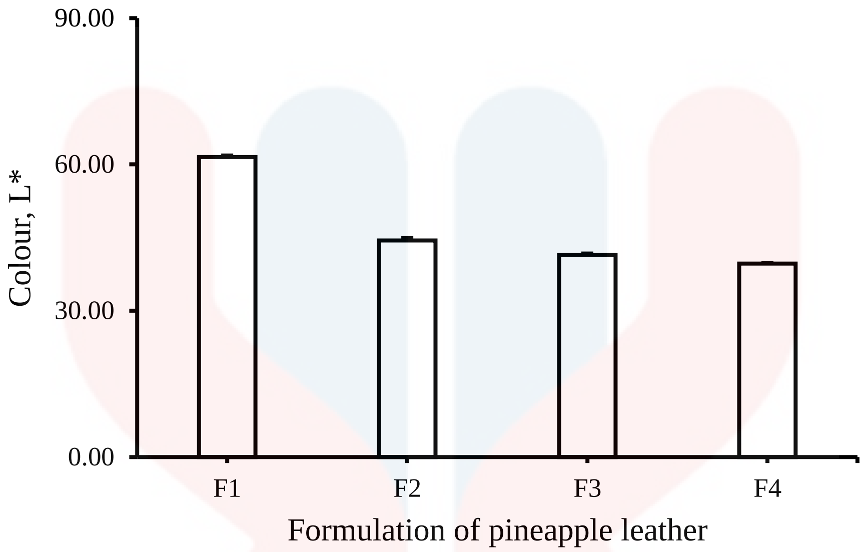

Figure 4.3.1: Colour L* of pineapple leather for formulation F1, F2, F3 and F4

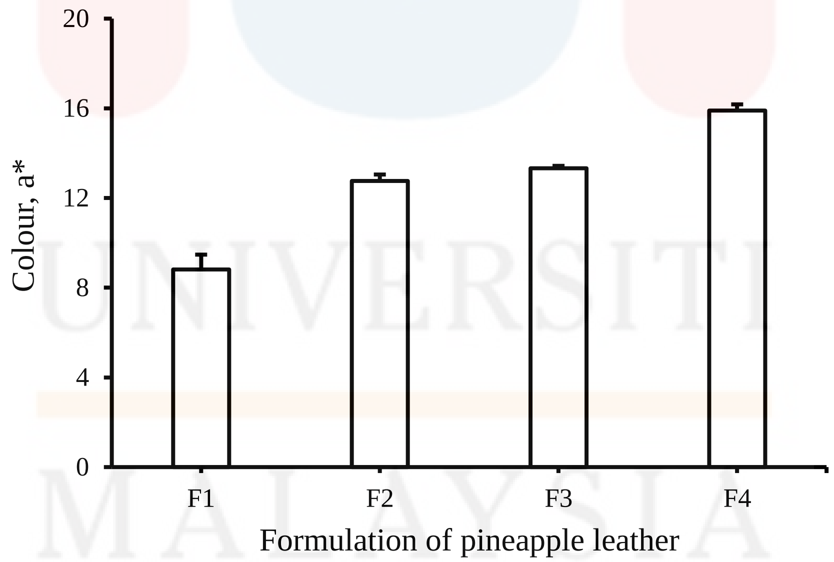

Figure 4.3.2: Colour a* of pineapple leather for formulation F1, F2, F3 and F4.

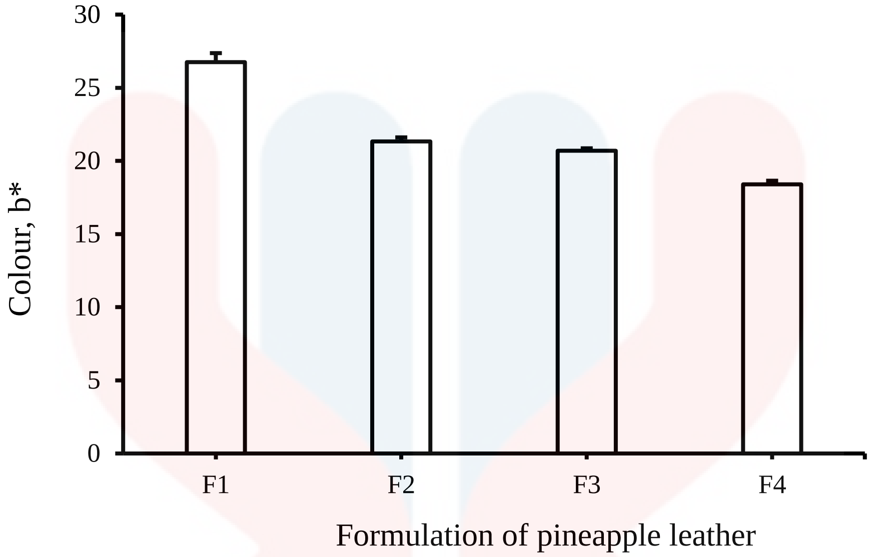

Figure 4.3.3: Colour b* of pineapple leather for formulation F1, F2, F3 and F4

Based on Figure 4.3.1, pineapple leather produced four formulations as a test for colour, L*. The colour, L* showed a significant difference with the value of $p \leq 0.05$ for all comparisons of colour, L*. To study the value of formulation difference for colour L* between comparisons for all formulations showed a decrease. The percentage for colour, L*, indicates the decrease for the percentage value. It showed the colour, L* value for F1 was 27.8 %, 32.63 % and 35.51 % according to the arrangement from F2, F3 and F4 formulations. In addition, the colour, L* for the percentage difference for F2 formulation, increased 10.67 % between F2 and F4. It was the highest value for the overall formulation comparison for the colour L* test. While for comparison, F2 and F3 increased only 6.69 %. The last comparison for the colour L* test was for formulations F3 and F4, which was 4.27 %. It shows a decrease compared to F4 in contrast to F2. The completed data on colour, L* is shown in Appendix G.

Figure 4.3.2 showed four types of formulations, F1, F2, F3 and F4 were analysed in the colour test, a*. In this study of colour, a* has obtained not significant values with the value $p > 0.05$ when comparing all formulations. The value for formulation difference of colour a* between comparisons for all formulations showed a decrease. The percentage of colour a* value indicates that all formulation comparisons were decreased. Comparison of colour, a* for percentage difference for F1 showed that F1 and F4 increase the most for all formulation percentage with 80.48 % compared to F1 and F3 with value of 51.31 % including percentage comparison with F1 and F2 that only 44.84 %. In addition, the difference between the percentages for F2 was also decreased for the percentage comparison colour, a* between F2 and F3, which was 4.47 %. However, the colour, a* for F2 and F4 had a slight increase of 24.61%. Further, F3 was lower than F4, which was 19.28 % in the colour, a* test. The completed data on colour, a* is shown in Appendix H.

Figure 4.3.3 showed four different formulations used in colour, b* test. The comparison colour, b*, between all F1 formulations showed a significant difference similarly with F2 and F4 and F3 and F4 based on the value of $p \leq 0.05$. However, there were no significant differences for colour, b* of F2 and F3 when the value of $p > 0.05$. The percentage of colour, b* value formulation for F1 and F2 was 20.26 %, the lowest value comparison among F1. The colour, b* values for F1 and F3 was 22.65 % was lower than F1 and F4, with a percentage difference was 31.96 %. On the other hand, colour, b* between F2 and F3 showed a minimal decrease of 3.0 %. Moreover, F2 and F4 showed an increase of colour, b* with a value of 13.74 % compared with F3, and F4 was 11.07 %. The completed data on colour, b* is shown in Appendix I.

The chromatic coordinates determine colour L*, a* and b* of which L* consists (black to white), representing its brightness range from 0 to 100. In addition, for the chromatic coordinates, a* represents (redness to green) describes the balance between green and red. In addition, the chromatic coordinates b* depict the colour (yellowness to blueness) balance in-minus for blue to in-plus for yellow (Lisiecka *et al*., 2019). Decreased colour brightness indicates a browning reaction during the fruit bar process (Salleh *et al*., 2017). In this research, F1 did not decrease colour brightness compared to F2, F3 and F4, where the formulation contained jaggery. The heat was a factor in the caramelisation process occur the reducing fruit leather's brightness (Setiaboma *et al*., 2019).

4.4 Water activity, a_w of Pineapple Leathers.

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

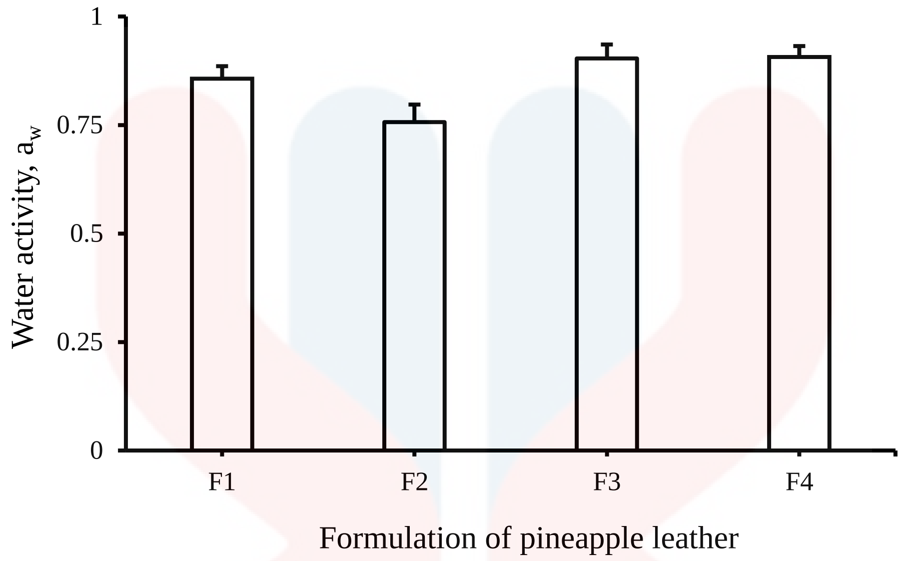

Figure 4.4.1: Water activity, a_w of pineapple leather for formulation F1, F2, F3 and F4.

Figure 4.4.1 presented the water activity, a_w for pineapple leather was tested. Therefore, the result water activity, a_w obtained was not significantly different for comparing F1 and F2 with the value $p > 0.05$. On the other hand, there was a significant difference between water activity, a_w for F1 and F3 and F4 $p \leq 0.05$. In addition, the difference between F2 and F3 for water activity, a_w, similarly with F2 and F4, have a significant difference when determined by $p \leq 0.05$. However, for comparing water activity, aw between F3 and F4, there was no significant difference with $p > 0.05$. Pineapple leather has been studied the results of percentage difference values for water activity, a_w. The result water activity, a_w obtained for the difference percentage was decreased. The water activity, a_w value for the difference between F1 and F2 was 11.63 %, increasing compared with F1 and F3, 4.65 % and F1 and F4, 5.81 %. In contrast, the difference between percentage values of F2 comparison for water activity, a_w between F3 including F4 was also decreasing with 18.42 % and 1.9.74 %. The lowest value was obtained for water activity, a_w between F3 and F4, with a value of 1.11 %, decreasing. The completed data on water activity a_w is shown in Appendix J.

Generally, the application of water activity can predict the growth of microorganisms, and it is useful to ensure the good shelf life of the food product. Therefore, the product's shelf-life stability can be predicted under known ambient storage conditions (Rahman *et al*., 2010). Fruit leather stability can determine the shelf life related to water activity, a_w. The water activity, a_w for fruit leather was less than 0.70 (Safaei *et al*., 2019). Fruit leather with intermediate water activity, a_w might have a lower storage time. In this study, the water activity for formulations F1, F2, F3, and F4 was more than 0.70. The microbial will develop under the water activity, a_w in range above 0.70 (Karki., 2011). The previous study shows that the fruit leather's water activity, a_w in the range of 0.31 to 0.71, prevents microorganism growth rapidly. However, water activity, a_w higher than 0.62 causes low microbial stability and lower storage time (Rahman., 2007).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In conclusion, the results obtained show that the formulation F3 was the satisfactory formulation in terms of physical properties of hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness. However, in terms of colour and water activity showed results that needed to be improved. A high percentage of jaggery affects the product's colour compared to products without jaggery. In addition, in terms of water activity, a_w also showed a short shelf life on the product because it did not reach the range level in the manufacture of fruit leather.

As a recommendation for further study, 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. In addition, pectin can affect the physical properties of fruit leather. Besides, the drying process needs careful monitoring to achieve a long shelf life to achieve the range of water activity of fruit leather. On the other hand, to strengthen the study, sensory evaluation can be conducted to assess customer preference. Therefore, fruit leather warranted further research development for commercialisation.

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APPENDIX A

The Completed Data of Hardness

Mean and Standard Deviation of hardness

	F1	F2	F3	F4
MEAN	74.5	110	44.83	54.33
S. D	2.78	10.33	2.02	3.21

T-test

Comparison between four formulations

%	T-test	p-value
-47.65	F1 VS F2	0.018494
39.83	F1 VS F3	0.001758
30.2	F1 VS F4	0.001055
59.23	F2 VS F3	0.00576
50.61	F2 VS F4	0.006517
-21.19	F3 VS F4	0.030638

A value of $p \leq 0.05$ 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	0.1	0.2
S. D	0.06	0.06	0.1	0.1

T-test

Comparison between four formulations

%	T-test	p-value
-133.33	F1 VS F2	0.333333
-233.33	F1 VS F3	0.091752
-566.67	F1 VS F4	0.064806
-42.86	F2 VS F3	0.370901
-130	F2 VS F4	0.091752
-100	F3 VS F4	0.112702

A value of $p \leq 0.05$ was considered significant

APPENDIX C

The Completed Data of Cohesiveness

Mean and Standard Deviation of cohesiveness

	F1	F2	F3	F4
MEAN	0.82	0.66	0.59	0.65
S. D	0.06	0.01	0.12	0.04

T-test

Comparison between four formulations

%	T-TEST	p-value
19.28	F1 VS F2	0.019037
28.05	F1 VS F3	0.019021
20.73	F1 VS F4	0.046726
10.61	F2 VS F3	0.197269
1.52	F2 VS F4	0.400985
-10.17	F3 VS F4	0.270868

A value of $p \leq 0.05$ was considered significant

APPENDIX D

The Completed Data of Springiness

Mean and Standard Deviation of springiness

	F1	F2	F3	F4
MEAN	0.16	0.16	0.2	0.14
S. D	0.01	0.01	0.09	0.01

T-test

Comparison between four formulations

%	T-test	p- value
0 %	F1 VS F2	0.5
-25	F1 VS F3	0.25201
12.5	F1 VS F4	0.064806
-25	F2 VS F3	0.232626
12.5	F2 VS F4	0.018875
30	F3 VS F4	0.176502

A value of $p \leq 0.05$ was considered significant

APPENDIX E

The Completed Data of Gumminess

Mean and Standard Deviation of gumminess

	F1	F2	F3	F4
MEAN	62.67	78	28.33	37.33
S. D	0.58	8.89	3.21	4.16

T-test

Comparison between four formulations

%	T-test	p-value
-24.46	F1 VS F2	0.04453
54.79	F1 VS F3	0.00131
40.43	F1 VS F4	0.0057
63.68	F2 VS F3	0.00244
52.14	F2 VS F4	0.01523
-31.77	F3 VS F4	0.07029

A value of $p \leq 0.05$ was considered significant

APPENDIX F

The Completed Data of Chewiness

Mean and Standard Deviation of chewiness

	F1	F2	F3	F4
MEAN	1	1.2	0.4	0.53
S. D	0.1	0.1	0.1	0.06

T-test

Comparison between four formulations

%	T-test	p- value
-20	F1 VS F2	0.1127
60	F1 VS F3	0.01334
47	F1 VS F4	0.00253
66.67	F2 VS F3	0.00258
55.83	F2 VS F4	0.00853
-32.5	F3 VS F4	0.09175

A value of $p \leq 0.05$ was considered significant

APPENDIX G

The Completed Data of Colour L*

Mean and Standard Deviation of Colour, L*

	F1	F2	F3	F4
MEAN	61.51	44.41	41.44	39.67
S. D	0.33	0.48	0.3	0.13

T-test

Comparison between four formulations

%	T-test	p-value
27.8	F1 VS F2	0.0003509
32.63	F1 VS F3	0.0001646
35.51	F1 VS F4	6.784E-05
6.69	F2 VS F3	0.0010021
10.67	F2 VS F4	0.0013969
4.27	F3 VS F4	0.0025761

A value of $p \leq 0.05$ was considered significant

APPENDIX H

The Completed Data of Colour a*

Mean and Standard Deviation of Colour, a*

	F1	F2	F3	F4
MEAN	8.81	12.76	13.33	15.9
S. D	0.66	0.29	0.11	0.28

T-test

Comparison between four formulations

%	T-test	p-value
-44.84	F1 VS F2	0.00172
-51.31	F1 VS F3	0.0026
-80.48	F1 VS F4	0.00191
-4.47	F2 VS F3	0.02437
-24.61	F2 VS F4	0.00224
-19.28	F3 VS F4	0.00306

A value of $p \leq 0.05$ was considered significant

APPENDIX I

The Completed Data of Colour b*

Mean and Standard Deviation of Colour, b*

	F1	F2	F3	F4
MEAN	26.75	21.33	20.69	18.4
S. D	0.61	0.28	0.17	0.25

T-test

Comparison between four formulations

%	T-test	p- value
20.26	F1 VS F2	0.0035
22.65	F1 VS F3	0.00248
31.96	F1 VS F4	0.00032
3	F2 VS F3	0.00646
13.74	F2 VS F4	0.00397
11.07	F3 VS F4	0.0046

A value of $p \leq 0.05$ 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	0.86	0.76	0.9	0.91
S. D	0.03	0.04	0.03	0.03

T-test

Comparison between four formulations

%	T-test	p-value
11.63	F1 VS F 2	0.06481
-4.65	F1 VS F3	0.00253
-5.81	F1 VS F4	0.0266
-18.42	F2 VS F3	0.0362
-19.74	F2 VS F4	0.0266
-1.11	F3 VS F4	0.3709

A value of $p \leq 0.05$ was considered significant

APPENDIX K

Illustration Of Instrument for Analysis Pineapple Leather

Brookfield CT3 Texture Analyser for physical properties analysis

Konica Minolta Chroma Meter CR-400 to observe colour analysis

Paw Kit for water activity, a_w analysis

Bio chef six tray Arizona Food Dehydrator for drying process

APPENDIX L

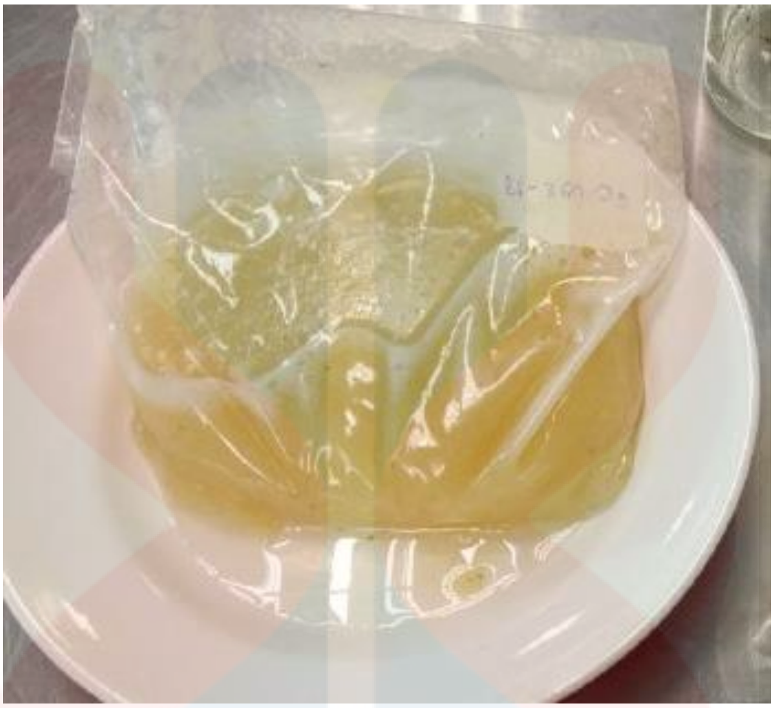
Illustration For Preparation of Pineapple Leather

Cutting the pineapple into small pieces

Weight the pineapple using digital weighing

Blended the pineapple into puree

The main ingredient in producing the pineapple leather



Pineapple puree

Jaggery

The uses of kitchen utensils in producing pineapple leather

Melting the jaggery

Heat pineapple puree and jaggery in medium heat

Temperature measurement

Mixture pours on the tray and spread

Pineapple leather before drying process (without jaggery)

Pineapple leather before drying process (with jaggery)

Formulation 1

Formulation 2

Formulation 3

Formulation 4

Formulation 1, 2, 3 and 4 after drying process

Pineapple leather roll (without jaggery)

Pineapple leather roll (with jaggery)