THESIS

*THE EFFECT OF ULTRASONICATION ON PHYSICAL AND CHEMICAL CHARACTERISTICS OF WHOLE FRESH PINEAPPLE (Ananas comosus (*L.*)* Merr*) QUEEN VARIETY*

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AGRICULTURAL PRODUCT TECHNOLOGY STUDY PROGRAM
DEPARTMENT OF AGRICULTURAL CULTIVATION
FACULTY OF AGRICULTURE
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RANI WIASTIAN. The Effect Of Ultrasonication on Physical and Chemical Characteristics of Whole Fresh Pineapple *(Ananas Comosus (*L.*)* Merr*)* Queen Variety (Supervised by **FILLI PRATAMA**).

Pineapple of queen variety contains high sugar content so it is not recommended for people with limited sugar consumption. One of the efforts that can be done was treating pineapple with ultrasonication. This study aimed to determine the effect of ultrasound frequency and duration on the physical and chemical characteristics of whole fresh pineapple *(Ananas Comosus (L.) Merr)* queen variety. This research was carried out from January until June 2021 at Laboratory of Agricultural Product Processing and Laboratory of Agricultural Product Microbiology, Department of Agricultural Technology, Faculty of Agriculture, Sriwijaya University. The experiment was designed as a Factorial Completely Randomized Design (RALF) with two treatment factors and each treatment was repeated three times. The first factor was the ultrasound frequency (20 kHz and 40 kHz) and the second factor was duration of contact (10, 15, 20, 25, 30 and 40 minutes). The observed parameters on pineapple were color (lightness (L^*), redness (a^*), yellowness (b^*) and total color difference (ΔE^*), texture, total sugar content, pH and vitamin C content. The results showed that the ultrasound frequency had a significant effect on the lightness (L^*) of whole fresh pineapple; duration of contact had a significant effect on yellowness (b^*) and pH of whole fresh pineapple. The interaction of ultrasound frequency and duration of contact had a significant effect on redness (a^*) of whole fresh pineapple. The A1B5 treatment (20 kHz, 30 minutes) was the best treatment based on the lowest total sugar content 10.87%°brix with a characteristic of pH 3.63, vitamin C content 11.03 mg/100 g, lightness 46.10%, redness 5.77, yellowness 15.00, total color difference 3.76 and texture 30.18 gf.

APPROVAL SHEET

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The thesis entitled " The Effect of Ultrasonication on Physical and Chemical Characteristics of Whole Fresh Pineapple (Ananas comosus (L.) Merr) Queen Variety' by Rani Wiastian had been examined and defended before the Examination Commission Thesis of the Faculty of Agriculture, Sriwijaya University on July 8th, 2021 and had been revised based on the suggestions of the examiners.

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Declare that all data and information contained in this thesis are the result of my own research activities under the supervision of my advisors, unless the sources are clearly mentioned. If in the future found any element of plagiarism in this thesis, then I am willing to accept academic sanctions from Sriwijaya University.

Thus, I make this statement consciously and without coercion from any party.

Indralaya, July 2021

Rani Wiastian

BIOGRAPHY

The writer was born in Palembang on August 11, 1999. The writer is the fourth of four children from parents named Mr. M. Alwi and Mrs. Siti Asyiah.

The educational history that the writer has taken were elementary school education (SD) at SD Negeri 140 Palembang in 2005, junior high school education (SMP) at SMP Negeri 11 Palembang in 2011, and high school (SMA) at SMA Negeri 13 Palembang in 2014. Since August 2017, the writer has been registered as a student of the Agricultural Product Technology Study Program, Department of Agricultural Technology, Faculty of Agriculture, Sriwijaya University through the SNMPTN.

The writer carried out field practice in Mr. Agus Setiawan's Tempe Processing Home Industry, from August to September 2020 and participated in the Real Work Lecture (KKN) for the Special Thematic Disaster Resilient Village (DESTANA) organized by Sriwijaya University in collaboration with the National Standardization Agency (BSN) in October until November 2020. The writer was recorded as a practicum assistant for Functional Food and Food Phytochemical courses in 2020 and Agricultural Product Analysis in 2021. The writer joined the Agricultural Technology Student Association (HIMATETA) organization and the Waqf and Islamic Studies Agency (BWPI), Faculty of Agriculture, Sriwijaya University as a member of the Secretariat Bureau.

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The writer hopes that this thesis can contribute ideas that are useful for readers and in the development of science. The writer realizes that this thesis is still not perfect. Therefore, suggestions and criticism from readers are needed to make this thesis even better.

Indralaya, July 2021

The Writer

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CHAPTER 1
INTRODUCTION

1.1. Background

Pineapple (*Ananas comosus* (L.) Merr) is one of the leading fruit commodities in Indonesia. Pineapple has a sweet and sour taste, so it has a refreshing sensation. Pineapple can be divided into five main varieties, namely *Cayenne, Queen, Maipure, Spanish* and *Abacaxi.* However, the varieties that are widely bred in Indonesia were the *Queen, Smooth Cayenne* and *Red Spanish* (Suyanti, 2010). The three varieties of pineapple have each different physical characteristics, taste and use. Among the three varieties, the *Queen* is mostly consumed in fresh form because it has a sweeter taste and a more fragrant aroma with a crunchy texture (Hadiati and Indriyani, 2008). In South Sumatra one of the areas that produce the *Queen* is Prabumulih.

Pineapple contained vitamins and minerals that are beneficial for our health (Hemalatha and Anbuselvi, 2013). The nutritional content contained in 100 g of pineapple consists of 81.2-86.2% water; 13.7 g carbohydrates; 1.4 g fiber; 0.54 g protein; 189.38 mg of minerals consisting of magnesium, iron, calcium, phosphorus, zinc and potassium; 130 IU of vitamin A; 0.079 mg of vitamin B1; 0.031 mg of vitamin B2; 0.489 mg of vitamin B3; 0.110 mg of vitamin B6; 24 mg of vitamin C; and 0.5-1.6 g of acid organic acids such as citric acid, malic acid and oxalic acid (Hossain et al., 2015). The *Queen* used in this study contains 15.20 g of sugar per 100 g of fruit in the form of fructose and glucose. Fructose and glucose were monosaccharide carbohydrates that were easily absorbed and digested by the body (Winarno, 2004). Additionally, pineapple had a glycemic index (GI) value of 68 so it is included in the fruit with a medium glycemic index (Hoerudin, 2012).

The high sugar content makes the *Queen* unsuitable to consume with impaired glucose tolerance or diabetes mellitus, because it can cause an increase in blood glucose levels after consumption. Therefore, it is necessary to make efforts to reduce sugar levels in pineapples so people with *diabetes mellitus* can consume the *Queen* without a significant increase in blood glucose. One of the efforts that can be done to reduce sugar content in the *Queen* is the ultrasonication method. The ultrasonication method was used in this study because it was environmentally friendly and did not use chemicals during the ultrasonication process (Chemat et al., 2011).

Ultrasonication is a method using ultrasonic sound waves with a frequency above the human hearing ability (> 20 kHz) (Chandrapala et al., 2012). Ultrasonic waves can propagate in liquid, gas and solid media. Ultrasonic waves propagating in a liquid medium can trigger the formation of gas bubbles and pressure that produced cavitation energy (Cui and Zhu, 2020). The cavitation energy produced can depolymerize polymer chains, disintegrate cell walls, denature enzymes and produce free radicals. The effect that can be generated from the application of the ultrasonication method to food ingredients can be in the form of changes in color and aroma, an increase or decrease in nutritional components and modification of minor components contained in foodstuffs (Pingret et al., 2013).

The application of the ultrasonication method has been widely carried out in various fields including in food processing such as increasing the extraction yield and the effectiveness of components or bioactive compounds in a food ingredient (Anugraini et al., 2018; Handayani et al., 2016). It also involves the evaluating of quality and quality of foodstuffs (Anugraini et al., 2018; Handayani et al., 2016), the evaluating of quality and quality of food (Luketsi et al., 2017), the formation of nanoparticles such as nanoemulsions (Siqhny et al., 2020), and the degradation of macromolecules into simpler compounds (Gogate and Prajapat, 2015). The application of the ultrasonication method in the food processing is influenced by the processing conditions (ultrasonic wave frequency, amplitude and ultrasonication time) as well as the type of the materials (Cui and Zhu, 2020). Both of these factors can affect the quality of the final product produced.

A research on the effect of ultrasonic waves with different contact lengths had been carried out by Sholihah *et al.* (2017) on mangosteen rind (20-40 kHz for 15, 30 and 45 minutes). The results showed that the mangosteen rind which was treated with ultrasonication for 45 minutes was the best treatment because it produced the highest extraction yield and anthocyanin content. Ordonez-Santos et al. (2017) reported that the vitamin C content of ceplukan fruit juice decreased with the longer ultrasonication time used (42 kHz for 10, 20 and 40 minutes) which were respectively, 25.45%, 56.50% and 78, 81%.

Adekunte et al. (2010) conducted a study on the effect of ultrasonication on the color and ascorbic acid content of tomato juice using an ultrasonic frequency of 20 kHz. The results showed that ultrasonic was able to cause color changes and degrade ascorbic acid contained in tomato juice. Golmohamadi et al. (2013) investigated the effect of ultrasonic frequencies (20, 490 and 986 kHz) on antioxidant activity and anthocyanin levels in red raspberry puree. The results showed that sonication with a frequency of 20 kHz was more effective than 490 and 986 kHz because it produced a higher percentage of antioxidant activity and anthocyanin levels in a shorter time. Both studies showed that the frequency of ultrasonic waves affects the physical and chemical characteristics of fruit juices and purees.

Research with the application of ultrasonic waves to fruit and its derivative products such as fruit juice, dried fruit and fruit puree had been carried out with the aim of evaluating the quality and the level of maturity as well as to determine the effect of ultrasonication on the physical, chemical and microbiological characteristics of fruit and its derivative products. Fernandes et al. (2008) reported that ultrasonication used as a pretreatment in the pineapple drying process was able to reduce the sugar content in pineapples by 23.2%. This research showed that the ultrasonication method had the potential to be applied directly to fresh fruit to produce fresh fruit with low sugar content.

Based on the results of pre-research that had been carried out, the ultrasonication method could reduce the sweet taste and cause color changes in the pineapple fruit. This study studied the effect of ultrasonication with ultrasonic wave frequencies and different contact lengths on the physical (color and texture) and chemical characteristics (total sugar content, pH, vitamin C content) of fresh fruit, especially the *Queen* variety.

1.2. Objective

This research was conducted to determine the effect of ultrasonic wave frequency and duration of contact on the physical and chemical characteristics of fresh pineapple (*Ananas comosus* (L.) Merr) of the *Queen* variety.

1.3. Hypothesis

The ultrasonication method was suspected to have a significant effect on the physical and chemical characteristics of fresh pineapple (*Ananas comosus* (L.) Merr) of the *Queen* variety.

CHAPTER 2
LITERATURE REVIEW

2.1. Pineapple

Pineapple (*Ananas comosus* (L.) Merr) is one of the leading commodities of tropical fruits in Indonesia. Pineapple grows in almost all parts of Indonesia because it is supported by Indonesia's tropical climate and can be obtained at any time because pineapple is a kind of fruit that is available throughout the season. Pineapple is one of the popular types of fruit and is very popular with the public because it has a distinctive aroma with a yellow flesh color and a combination of sweet and sour flavors. At the beginning, pineapple was only known as a garden plant, then slowly developed and expanded until it reached plantations (Ardiansyah, 2010).

According to Nasela (2017), the taxonomy or systematics of pineapple plants is as follows:

Kingdom/ Kingdom	: Plantae
Division/ Division	: Magnoliophyta
Classis/ Class	: Liliopsida
Ordo/ Order	: Bromeliales
Familia/ Family	: Bromiliaceae
Genus/ Genus	: *Ananas Mill*.
Spesies/ Species	: *Ananas comosus* (L.) Merr
Binomial name	: *Ananas comosus* L merr
Common name	: Pineapple

Pineapple belongs to the family of *Bromeliaceae* which is terrestrial or can grow on the ground using its roots. Pineapple is an herb that can live in various seasons (perennial). This plant is classified in the monocot class which is annual and has a flower and fruit arrangement at the end of the stem. Pineapple stems have the characteristics of club-shaped and very short internodes; they also covered by leaves and roots (Ardiansyah, 2010) as can be seen in Figure 2.1.

Source: www.cybex.pertanian.go.id

Figure 2.1. Pineapple

Pineapple that is ready to be harvested can be identified by its physical characteristics, such as the hard, clean, and dry texture of the fruit. Other physical characteristics include the fully grown (dull and wide) part in the eyes of the fruit as well as the exixtence of a fragrant aroma. Pineapple that is ready to be consumed freshly can also be marked by the top part of the fruit which is greenish yellow; besides, the diameter of the fruit has reached approximately 9 cm; and the fruit is having a normal shape which means the fruit is free from pests or diseases and the fruit is not broken, bruised or injured due to impact. and friction; additionally, the fruit has a neat and intact fruit crown (Nasela, 2017).

The main economically important part of the pineapple plant is the fruit. The taste of the fruit is sweet to slightly sour, so it is favored by wider community. In addition, pineapple contains a fairly high and complete nutrition. In terms of nutritional content, pineapple has a source of regulatory substances, namely vitamins and minerals that are needed by the human body. Vitamins and minerals can be useful for smooth metabolism in the digestion of food which is very vital so that it can maintain the health of those who consume them (Hemalatha and Anbuselvi, 2013). The nutrients contained in 100 g of pineapple can be seen in Table 2.1.

Table 2.1. Nutrients contained in 100 g of pineapple

No.	Nutritional Composition	Amount
1.	Energy	52 calories
2.	Fibre	1.40 g
3.	Carbohydrate	13.7 g
4.	Protein	0.54 g
5.	Mineral	
	5.1. Iron	0.28 mg
	5.2. Magnesium	12 mg
	5.3. Calsium	16 mg
	5.4. Fosfor	11 mg
	5.5. Zinc	0.10 mg
	5.6. Potassium	150 mg
6.	Vitamin	
	6.1. Vitamin A	130 IU
	6.2. Vitamin B1	0.079 mg
	6.3. Vitamin B2	0.031 mg
	6.4. Vitamin B3	0.489 mg
	6.5. Vitamin B6	0.110 mg
	6.6. Vitamin C	24 mg
7.	Asam Organik	
	7.1. Organic Acid 7.2. Malic Acid 7.3. Oxsalic Acid	0.5-1.6 g
8.	Water	81.2-86.2%

Source : Hossain *et al.* (2015)

Pineapple has many benefits for health. Pineapple can shed excess fat deposits in the body. In addition, pineapple is also beneficial for the health of the body, including a cure for urinary tract disorders, nausea, flu, hemorrhoids, and anemia. Even skin diseases such as itching, eczema and anemia can also be cured by smearing pineapple juice on the problematic part of the skin. Pineapple is able to increase the body's immune system because it contains vitamin A, vitamin C, calcium, phosphorus, magnesium, iron, sodium, potassium, dextrose, sucrose and bromealin enzymes stored in the pineapple. Pineapple's high fiber content is also good for treating constipation. Consuming pineapple means the same as taking constipation medicine, so in can help to smoothen the defecation process. Pineapple is also good enough to be consumed by people who are sick because it contains substances that can increase drug absorption into the body (Ardiansyah, 2010).

Consuming pineapple exessively can increase the blood sugar levels. Ripe pineapple contains a fairly high sugar content, namely 15.20 g of carbohydrates per 100 g of fruit in the form of fructose and glucose. Fructose and glucose are monosaccharide carbohydrates that are easily absorbed and digested by the body

(Winarno, 2004) and also pineapple has a glycemic index (GI) value of 68 so it is included in moderate GI fruit (Hoerudin, 2012). The high sugar content makes it hard to people with impaired glucose tolerance or diabetes mellitus to consume the *Queen* because it can cause an increase in blood glucose levels after consumption (Ardiansyah, 2010).

2.1.1. The Varieties of Pineapple

According to Ardiansyah (2010), pineapple varieties or cultivars that have been cultivated in Indonesia are the Cayenne, Queen and Spanish groups. However, based on the shape of the leaves and fruit, pineapple plants can be grouped into four groups, namely as follows:

2.1.1.1. The *Cayenne*

Pineapple that is included in the type of *Cayenne* is *Smooth Cayenne* and *Cayenne Lisse*. The characteristics of the C*ayenne* include smooth leaves or no thorns, even if the thorns are only found at the tips of the leaves, the large fruit is bubbling with a fruit weight of about 1.8-2.5 kg, has a sweet and sour taste with a strong aroma, the fruit eyes are slightly swollen. flat, yellowish green skin color with a small fruit crown and contains high water content. Furthermore, the content of vitamin C is low, which is around 0.2 mg/L of fruit juice. The *Cayeene* is generally used more often in the canned pineapple industry (Ardiansyah, 2010). The *Cayenne* is bred in several areas in Indonesia such as Palembang, Salatiga, Bukit Tinggi, Sarawak, Pontianak, Probolinggo, Purbalingga and Palangkaraya (Nasela, 2017). The physical appearance of the *Cayenne* can be seen in Figure 2.2.

Source: www.argowindo.com
Figure 2.2. The *Cayenne*

2.1.1.2. The *Queen*

The *Queen* is mostly consumed in fresh form because it has a sweeter taste, more fragrant aroma than other varieties and golden yellow flesh with a crunchy texture and is not transparent (Hadiati and Indriyani, 2008). The characteristics of the *Queen* are having shorter leaves.. The leaves are also long thorny ones, which generally bend backwards. This type of pineapple is avrelatively small size fruit weighing around 1 kg with oval shape resembling a cone to cylindrical. It has prominent fruit eyes and reddish yellow fruit skin color. Meanwhile, the size of the crown of the fruit is large, the color of the flesh is golden yellow and the flesh of the fruit is fibrous. Additionally, the content of moderate vitamin C is 0.34 mg/L (Ardiansyah, 2010). Areas known to produce the *Queen* are Bogor, Palembang (especially Prabumulih) and Kediri, but the *Queen* can also be found in Pontianak, Palangkaraya, Purwokerto, Jember and Bondowoso (Nasela, 2017). The physical appearance of the *Queen* can be seen in Figure 2.3.

Figure 2.3. The *Queen*

2.1.1.3. The *Spanish*

The *Spanish* has a characteristic that is high fiber content. In general, the characteristics of the Spanish variety pineapple is is a quite large fruit with a weight ranging from 0.9-1.8 kg. It also has deep fruit eyes so that a lot of the flesh is wasted when peeling the skin. It has spiked leaves, rough fruit skin and sharp fruity aroma. The *Spanish* is more likely to be used as an ingredient for making paper or textiles.

Regions in Indonesia that are known as spanish pineapple producing areas include Bangkalan, Kendal, Bali and Palangkaraya (Nasela, 2017).

The *Spanish* can be classified into two cultivars, namely *Singapore Spanish* or *canning* or *ruby* and *Red Spanish* or red pineapple. *Singapore Spanish* or *canning or ruby* characteristics are a cylindrical fruit, yellowish green color when ripe, golden yellow flesh, smooth and thornless leaves like Cayenne and Hilo pineapples and widely grown in Malaysia. Meanwhile the *Red Spanish* or red pineapple has many characteristics, such as round egg like shape, yellow to red color when ripe, white flesh color, and sharp spine leaves. *Red Spanish* is widely grown in Puerto Rico and Cuba. The shape of the *Red Spanish* can be seen in Figure 2.4. The content of vitamin C in *Red Spanish*is low at 0.29 mg/L fruit juice while *Singapore Spanish* has a quite high vitamin C, which is 0.41 mg/L fruit juice (Ardiansyah, 2010).

Source: www.bacaterus.com

Figure 2.4. The *Red Spanish*

2.1.1.4. The *Abacaxi*

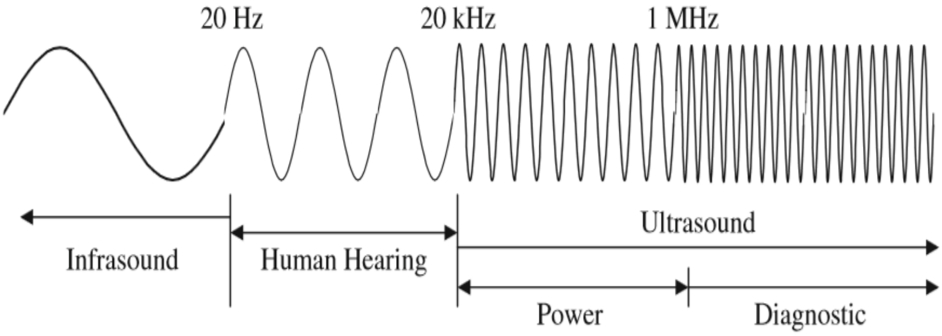
The characteristics of the *Abacaxi* are medium-sized fruit with long stalks, cylindrical to cone-shape. The ripe fruit is yellowish green but some are red. In general, the flesh is white. The *Abacaxi* weight of 1.5 kg and has small leaves. It also has long and rough thorns and a small fruit core. In addition, the *Abacaxi* has a slightly sour taste with a fairly high vitamin C content of 0.6 mg/L fruit juice. The *Abacaxi* is only grown in Brazil and only marketed locally. In general, the *Abacaxi* is not suitable for use in cans (Ardiansyah, 2010). The physical appearance of the *Abacaxi* can be seen in Figure 2.5.

Source: www.allfresh.co.id

Figure 2.5. The *Abacaxi*

2.2. Ultrasonication

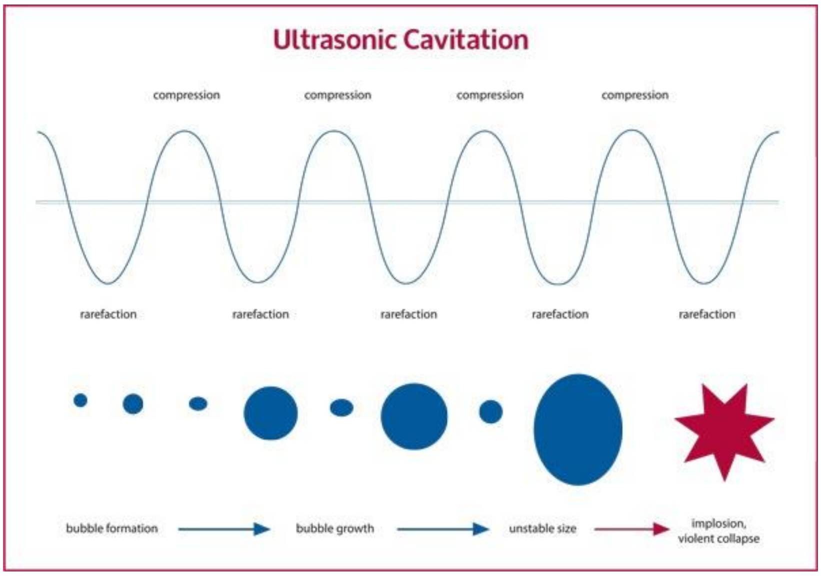
Ultrasonication is a method using ultrasonic sound waves with a frequency above the ability of human hearing (> 20 kHz). The type of the sound wave is determined by its frequency with the sound wave spectrum which can be seen in Figure 2.6. Infrasound waves are sound waves with frequencies below the human hearing ability. The human hearing range is from 20 Hz to 20 kHz. While ultrasonic sound waves refer to sound waves that are above this range. The spectrum of ultrasonic sound waves can be divided into two zones, namely the spectrum which is generally used which refers to the frequency range from 20 kHz to about 1 MHz and the diagnostic ultrasonic spectrum which has a frequency of more than 1 MHz and is used mainly for medical and industrial imaging purposes (Kentish and Ashokkumar , 2011).



Source: Kentish dan Ashokkumar (2011)

Figure 2.6. Sound wave spectrum

Ultrasonic waves can propagate through liquid, gas and solid media. Energy changes that occur in the ultrasonication process are vibrations produced by the transducer on the sonicator that can convert electrical energy into acoustic energy. The mechanism that occurs in the ultrasonication method in food processing using liquid media, namely ultrasonic sound waves propagating through a liquid medium will cause gas bubbles to form and pressure capable of vibrating water. This phenomenon is called the phenomenon of acoustic cavitation as shown in Figure 2.7. The gas bubbles and the resulting pressure will travel towards the sample. Over times, the gas bubbles formed will get bigger and become unstable then the gas bubbles will burst. When gas bubbles burst and then collide with the sample surface, it will produce effects such as particle damage and cell walls that can affect the nutrient content and physical properties of the material (Chemat et al., 2019).



Source: www.hielscher.com

Figure 2.7. The phenomenon of acoustic cavitation on ultrasonication

The application of the ultrasonication method has been widely carried out in various fields including food processing such as extracting bioactive compounds in a food ingredient (Wen et al., 2018). It is also applied in evaluating the quality of food ingredients (Luketsi et al., 2017), in emulsification process (Siqhny et al. , 2020), in fermentation process (Ojha et al., 2016) and in degrading macromolecules into simpler compounds (Airlangga et al., 2019; Gogate and Prajapat, 2015). The ultrasonication method is included in the process technology without involving heat (non-thermal processing technology) which can be applied in the food processing process. The advantage of applying the ultrasonication method over other methods in food processing is that in general the use of sound waves is considered safer, non-toxic and environmentally friendly (Kentish and Ashokkumar, 2011). In addition, ultrasonication can be combined with thermal methods, namely heat (thermosonication), non-thermal methods, namely pressure (manosonication) or a combination of the two (manothermosonication) so that they can provide a more effective influence in the inactivation process of microbes that cause damage. The use of the ultrasonication method can also increase the extraction yield, reduce the time and temperature used in processing and minimize damage to color, aroma, and other nutritional components during the process (Ravikumar et al., 2017).

The effect that can be generated from the application of the ultrasonication method to food ingredients can be in the form of changes in color and aroma, an increase or decrease in nutritional components and modification of minor components contained in foodstuffs (Pingret et al., 2013). Ultrasonic waves are widely applied to fruit and their derivative products such as fruit juices (Abdullah and Chin, 2014; Zinoviadou et al., 2015), dried fruit (Fernandes et al., 2008; Rodrigues and Fernandes, 2007) and fruit purees (Golmohamadi et al. ., 2013).

Ultrasonic treatment of fruit and its derivative products can cause physical and chemical changes. Aadil et al. (2013) stated that grapefruit juice had an increase in quality after being given ultrasonic treatment. The quality improvement that occurred included an increase in ascorbic acid, total phenol, flavonoids and flavonols for all samples of grapefruit juice after treatment compared to control samples. However, ultrasonic treatment had no effect on the pH value, acidity and total dissolved solids and underwent color degradation of grapefruit juice after treatment.

The application of the ultrasonication method in the food processing process is influenced by the processing conditions including the frequency of ultrasonic waves, the amplitude and length of time for ultrasonication and the type of material (Cui and Zhu, 2020). Gonzales-Centeno et al. (2014) stated that the use of ultrasonic wave frequencies (40 kHz, 80 kHz and 120 kHz) and ultrasonication time (5 minutes, 15 minutes and 25 minutes) affected the total phenol and total flavonoids of grape pomace. The results showed that the frequency of 40 kHz for 25 minutes was the best treatment because it was able to extract total phenols and flavonoids in grape pomace optimally.

CHAPTER 3
RESEARCH METHODOLOGY

3.1. Time and Place

This research was carried out from January to June 2021 at the Agricultural Product Processing Laboratory and Agricultural Microbiology Laboratory, Agricultural Products Technology Study Program, Agricultural Technology Department, Faculty of Agriculture, Sriwijaya University, Indralaya.

3.2. Tools and Materials

The tools used in this study were: 1) aluminum foil, 2) glass stirring rod, 3) blender, 4) burette, 5) color reader (Kinoka Minolta, Japan), 6) glass funnel, 7) Erlenmeyer, 8) Beaker glass, 9) measuring cup, 10) filter paper, 11) measuring flask. 12) analytical balance (Ohaus, USA), 13) pH meter (Hanna, Romania), 14) dropper pipette, 15) polypropylene plastic, 16) plate white standard, 17) needle-type probe (TA 9), 18) refractometer (Atago, USA), 19) refrigerator box freezer, 20) spatula, 21) stative, 22) texture analyzer (Brookfield LFRA Texture Analyzer), and 23) ultrasonic processor (Cole Parmer 6 L with digital timer and heat, 230 VAC, 40 kHz, China).

The materials used in this study were: 1) "Aqua" mineral water, 2) distilled water, 3) pineapple (*Ananas comosus* (L.) Merr) *Queen* variety, 4) 1% starch solution, 5) acid buffer solution (pH 4), 6) alkaline buffer solution (pH 10), 7) neutral buffer solution (pH 7), and 8) 0.01 N iodine solution.

3.3. Research Methods

This study used a Factorial Completely Randomized Design (CRD) with two treatment factors, namely (A) ultrasonic wave frequency and (B) contact time. Each treatment combination was repeated three times with the details of the treatment as follows:

1. Factor A (ultrasonic wave frequency)

   A_1 = 20 kHz

   A_2 = 40 kHz

2. Factor B (contact time)

B_1 = 10 minute

B_2 = 15 minute

B_3 = 20 minute

B_4 = 25 minute

B_5 = 30 minute

B_6 = 40 minute

3.4. Data Analysis

Observational data obtained were processed using analysis of diversity (ANOVA). Treatments that had a significant effect were further tested using the Honestly Significant Difference (HSD) test at the 5% level.

3.4.1. Statistical Analysis

The data obtained were then processed using statistics. Data processing in this study was carried out quantitatively by using data processing techniques of parametric statistical analysis referring to Gomez and Gomez (1995). The general model of factorial Completely Randomized Design (CRD) with two treatment factors used in this study is as follows:

Description:

= observation value

= average value

= effect of ultrasonic wave frequency treatment

= effect of contact time treatment

= interaction effect of ultrasonic wave frequency treatment and contact time

= test error (error)

The measurement data was processed using parametric statistical analysis. Analysis of variance in statistics can be seen in Table 3.1.

Table 3.1. List of Factorial Completely Randomized Design Diversity Analysis (RALF)

Source Of Diversity (SK)	Degree of Freedom (db)	Total of squared (JK)	Total of squared Middle (KT)	F_{count}	F_{table} 5%
Treatment	$V_1 = (m.n) - 1$	JKP	JKP/ V_1	KTP/KTG	(V_1, V_5)
Factor A	$V_2 = m - 1$	JKA	JKA/ V_2	KTA/KTG	(V_2, V_5)
Factor B	$V_3 = n - 1$	JKB	JKB/ V_3	KTB/KTG	(V_3, V_5)
Interaction AB	$V_4 = (m-1)(n-1)$	JKAB	JKAB/ V_4	KTAB/KTG	(V_4, V_5)
Galat	$V_5 = V_6 - V_1$	JKG	JKG/ V_5		
Total	$V_6 = (m.n.r)-1$	JKTotal	JKTotal/ V_6		

Source: Gomez dan Gomez (1995)

The significance of the variance analysis was carried out by comparing Fcount and Ftable at the 5% level with the following comparison basis:

1. If $F_{count} > F_{table}$ 5%, it was stated that the treatment factor had a significant effect and was marked (*).
2. If $F_{count} < F_{table}$ 5%, it was stated that the treatment factor had no significant effect and was marked (ns).

If the results of the analysis of variance showed that F_{count} was bigger than F_{table} was then continued with the HSD test (Honestly Significant Difference) to find out the mean difference in each experiment. The formula used for the HSD test was:

$$HSD = Q\ (p,v) \times$$

$\alpha = \sqrt{\frac{}{}}$, for ultrasonic wave frequency treatment

$\beta = \sqrt{\frac{}{}}$, for long contact treatment

$\alpha\beta = \sqrt{\frac{}{}}$, for treatment interactions

Description:

Q = value in table q at 5% test level

p = number of treatments

v = degrees of error free (error)

= common mean standard error

α = ultrasonic wave frequency treatment

β = contact length treatment

αβ = interaction between ultrasonic wave frequency treatment and contact time

KTG = galat center squared

r = number of repetitions

The level of accuracy of a study could be known by using the Coefficient of Diversity (KK) test (Gomez and Gomez, 1995). If the value of the Coefficient of Diversity (KK) obtained was less than 15%, this study had a good accuracy. The formula used to calculate the Coefficient of Diversity (KK) was as follows:

$$KK\ (\%) = \frac{\sqrt{\quad}}{\quad} \times 100\%$$

Description:

KK = coefficient of diversity

KTG = galat center squared

Y = the average value of the total experimental data

3.5. Procedures

3.5.1. Preparation of Whole Fresh Pineapple Fruit Samples

The main ingredient used in this research is the *Queen* variety of pineapple from Prabumulih, South Sumatra. The level of maturity of the pineapple to be used was fully ripe, marked by the entire yellow skin color. Pineapple was cleaned by peeling the skin and eyes of the fruit. Furthermore, the pineapple fruit was washed and analyzed for the observed parameters before the whole pineapple was treated. After that, whole pineapples with fruit weights ranging from 500 g-760 g were put in polypropylene plastic and 1 liter of "Aqua" mineral water was added. Next, the pineapple was ready to be put into the sonicator which already contained 3 liters of water.

3.5.2. Ultrasonic Process of Whole Fresh Pineapple

The working of the ultrasonication process referred to the research of Fernandes et al. (2008) which was modified as follows:

1. Water was put into the ultrasonic bath as much as 3 liters.
2. The sonicator was turned on then prepared in advance for 2 minutes at 30^o C.
3. After the sonicator was prepared, the pineapple was put into the sonicator for 10 minutes, 15 minutes, 20 minutes, 25 minutes, 30 minutes and 40 minutes with ultrasonic wave frequencies of 20 kHz and 40 kHz at 30℃.
4. After that, removed the pineapple and let it sit for a while at room temperature.

Then analyzed the physical and chemical characteristics of pineapple after ultrasonication.

3.6. Parameters

The Parameters observed in this study included physical and chemical characteristics of pineapple which were carried out before (control) and after being given treatment. Physical characteristics included texture analysis on hardness and color analysis. While the chemical characteristics included analysis of total sugar content, analysis of vitamin C levels and pH.

3.6.1. Analysis of Physical Characteristics of Whole Fresh Pineapple

3.6.1.1. Texture on Hardness

The texture analysis on hardness was carried out using the Texture Analyzer (Brookfield LFRA Texture Analyzer). How texture analysis worked according to Farida et al. (2006) were as follows:

1. A needle type probe (TA 9) or needle was attached to the texture analyzer.
2. The sample was placed directly under the needle type probe (TA 9) or needle.
3. The speed of the texture analyzer was set at 0.1 mm/second with a distance of 5 mm and a trigger force of 10 g.
4. The surface of the sample would be punctured by a needle-type probe.
5. The final load value in gram force (gf) was recorded on the device.

3.6.1.2. Color

The color analysis was performed using the Color Reader (Kinoka Minolta) using the CIE Lab method for L*, a*, b* and E*. According to Munsell (1997), the way color analysis worked was as follows:

1. The Color Reader tool was turned on and then calibrated first by attaching the optical head to a white standard plate.
2. In the menu selection, the function keys L*, a*, b* were activated.
3. The sample was put into a transparent container (clear plastic) then attached to the optical head and then pressed the start button.
4. The values of L*, a*, b* listed on the instrument were recorded and then the total value of the color difference (ΔE*) of the sample and standard was calculated using the following formula:

$$\Delta E^* = \sqrt{(\quad)\quad(\quad)\quad(\quad)}$$

Description:

$\Delta L^* = L^*_{\text{sample}} - L^*_{\text{standard}}$

$\Delta a^* = a^*_{\text{sample}} - a^*_{\text{standard}}$

$\Delta b^* = b^*_{\text{sample}} - b^*_{\text{standard}}$

3.6.2. Analysis of the Chemical Characteristics of Whole Fresh Pineapple

3.6.2.1. Total Sugar Level

The analysis of total sugar content was carried out using a refractometer based on Sudarmadji et al. (2007) in Arifa et al. (2014) which had been modified. The way the analysis of total sugar content works was as follows:

1. Pineapple flesh, either the control sample or the sample that had been treated, was cut into small pieces and then mashed.
2. Pineapple flesh that has been finely filtered using filter paper and the filtrate is taken as much as 1 teaspoon or about 1 mL.

3. The sample filtrate was dripped onto the refractometer lens.
4. The value of the total sugar content (%°brix) of the sample printed on the refractometer monitor was then recorded.

3.6.2.2. pH

The analysis of the pH value was carried out using a pH meter (Hanna) based on Sudarmadji et al. (1997). The way pH analysis worked was as follows:

1. Pineapple flesh, either the control sample or the sample that had been treated, was cut into small pieces and then mashed.
2. The finely chopped pineapple flesh was filtered using filter paper and 5 mL of the filtrate was taken and then put into a beaker glass.
3. Before used, the electrodes on the pH meter were standardized using an acid buffer solution (pH 4), a neutral buffer solution (pH7) and alkaline buffer solution (pH 10) then cleaned using distilled water and dried.
4. The electrode was dipped into the sample filtrate, then waited until the reading was stable.
5. The results of pH measurements listed on the tool were then recorded.

3.6.2.3. Vitamin C levels

The analysis of vitamin C levels was carried out using the iodimetric method based on Sudarmadji et al. (1997). The way the analysis of vitamin C levels works was as follows:

1. Pineapple flesh was cut into small pieces and then mashed using a blender until it formed a slurry.
2. A total of 25 g of slurry was put into a 100 mL volumetric flask and distilled water was added to the mark. Then filtered using filter paper to separate the filtrate.
3. Pipetted sample filtrate taken as much as 25 mL then put into Erlenmeyer then added 2 mL 1% starch solution.
4. Next, it was titrated using 0.01 N iodine solution until it reached the end point (marked by a color changed from colorless to blue). The content of vitamin C could be calculated by formula:

$$\text{Vitamin C Levels (mg/100g)} = \frac{(\quad\quad\quad)}{\quad}$$

Description:

: Iodin volume (mL)

0,88 : 0.88 mg Vitamin C (ascorbic acid) equivalent to 1 mL of 0.01 N

Fp : Dilution factor

W : Sample weight (g)

CHAPTER 4
RESULTS AND DISCUSSION

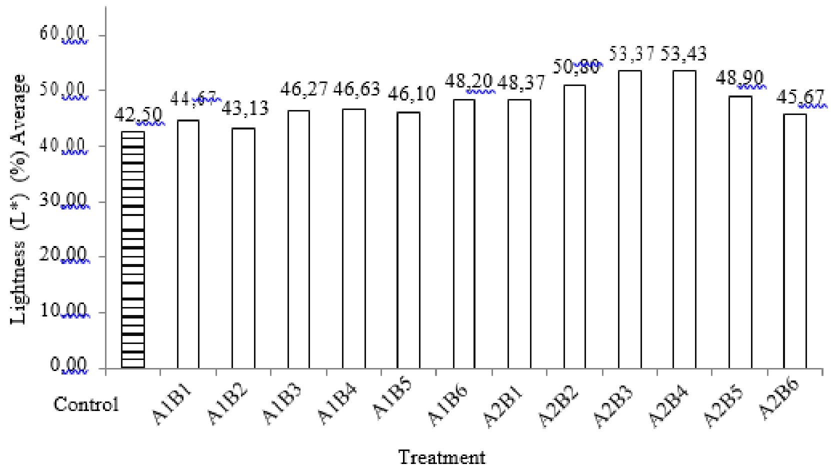
4.1. Physical Characteristics of Whole Fresh Pineapple

4.1.1. Color

Color is one of the quality indicators that can be related to fruit freshness so it is often used in evaluating the quality and consumer acceptance of fresh fruit. The color of the fruit is due to the presence of pigments that are naturally contained in the fruit. The yellow color of the pineapple flesh is due to the presence of carotenoid pigments (Nugraheni, 2014 in Syaiful et al. 2020). Carotenoid pigments are stored in plastids (chromoplasts) and can cause yellow, orange and red-orange colors in fruit (Winarno, 2004). Color analysis of whole fresh pineapple that had been peeled was carried out on the outer surface of the fruit including the lightness value (L*), redness (a*), yellowness (b*) and total color difference (ΔE*).

4.1.1.1. Lightness (L*)

Lightness (L*) states the brightness level of a food ingredient with a value ranging from 0-100%. The greater the value of lightness (closer to 100%), the brighter (white) the color of the food material is and vice versa, the smaller the lightness value (towards 0%), the darker or darker the color of the product (Soebroto et al., 2012). The results showed that the average lightness value of pineapple after ultrasonication treatment ranged from 43.13% to 53.43%, while the lightness value of whole fresh pineapple without ultrasonication treatment (control) was 42.50%. The average lightness value (L*) of whole fresh pineapple with ultrasonic wave frequency treatment and contact time can be seen in Figure 4.1.



Description :

A_1 : 20 kHz
A_2 : 40 kHz
B_1 : 10 minutes
B_2 : 15 minutes
B_3 : 20 minutes
B_4 : 25 minutes
B_5 : 30 minutes
B_6 : 40 minutes

Figure 4.1. Average lightness value (L*) of whole fresh pineapple

Based on Figure 4.1. It can be seen that fresh whole pineapple after ultrasonication treatment had a higher lightness value than whole fresh pineapple without treatment (control). The lightness value tended to increase for samples with 20 kHz and 40 kHz frequency treatments (10, 15, 20, and 25 minutes), but a decrease in the lightness value occured in samples with 40 kHz treatment (30 and 40 minutes). The decrease in the lightness value was thought to occur due to a browning reaction (Labuza et al., 1992; Rawson et al., 2011). Meanwhile the increase in the lightness value was due to the fading of the yellow color in whole fresh pineapple after ultrasonication. This was thought to occur due to the homogenization effect produced by the process of ultrasonication (Tiwari et al., 2008).

The results of the analysis of variance (Appendix 4) showed that the frequency of ultrasonic waves (factor A) significantly affected the lightness value, while the length of contact (factor B) and the interaction between the two treatment factors had no significant effect on the lightness of whole fresh pineapple after ultrasonication. Thus, the Honest Significant Difference (HSD) test was carried out at a level of 5%. The effect of ultrasonic wave frequency on the lightness value (L*) of whole fresh pineapple can be seen in Table 4.1.

Table 4.1. HSD test level 5% effect of ultrasonic wave frequency onlightness value (L*) of whole fresh pineapple

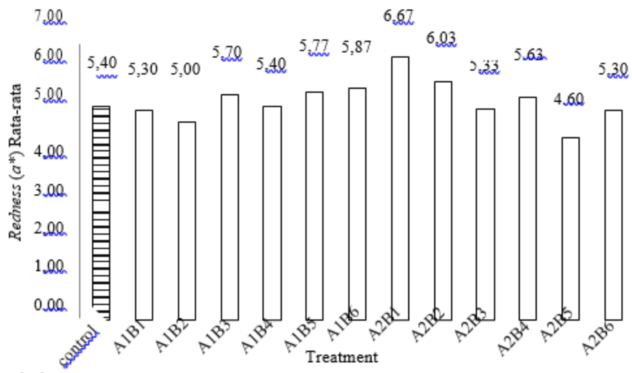
Frequency	*Lightness* (*L**) average	HSD 5% = 3,915
A1 (20 kHz)	45,83	a
A2 (40 kHz)	50,09	b

Description: Numbers followed by the same letter in the same column indicate that the treatment was not significantly different at the 5% level.

The results of the 5% HSD test (Table 4.1.) showed that treatment A1 (20 kHz) was significantly different from treatment A2 (40 kHz). The higher the frequency of ultrasonic waves, the higher the value of lightness. This showed the yellow color on the outer surface of the pineapple was getting faded. The higher the frequency of ultrasonic waves, the more gas bubbles formed, resulting in an increasing cavitation energy. Increased cavitation energy could cause cell damage to the fruit, including the plastid membrane, allowing carotenoids to be dispersed outside the cell; this could affect the color of the final product (Wang et al., 2019).

4.1.1.2. *Redness (a*)*

Redness (a*) is a color component that represents the red to green color spectrum. A product is said to be red if the measured value is positive and green if the value is negative (Dinar et al., 2012). The results showed that the average redness value (a*) of whole fresh pineapple after ultrasonication treatment ranged from 4.60 to 6.67, while the redness value (a*) of whole fresh pineapple without ultrasonication treatment (control) was 5 ,40. The average redness value (a*) of whole fresh pineapple with ultrasonic wave frequency and contact time is presented in Figure 4.2.



Description :

A_1 : 20 kHz B_1 : 10 minute B_3 : 20 minute B_5 : 30 minute
A_2 : 40 kHz B_2 : 15 minute B_4 : 25 minute B_6 : 40 minute

Figure 4.2. The average redness value (a*) of whole fresh pineapple

The results of the analysis of variance (Appendix 5) showed that the frequency of ultrasonic waves (factor A) and the length of contact (factor B) had no significant effect on the redness value, but the interaction between the two treatment factors had a significant effect on the redness value of whole fresh pineapples. Thus, a further test of the Honest Significant Difference (HSD) was carried out at a level of 5%, The effect of the interaction of ultrasonic wave frequency and contact time on the redness value (a*) of whole fresh pineapple can be seen in Table 4.2.

The results of the 5% HSD test (Table 4.2.) showed that the A2B5 treatment (40 kHz, 30 minutes) was not significantly different from the A1B2 treatment (20 kHz, 15 minutes) but significantly different from the other treatments. The increase in the frequency of ultrasonic waves and the length of contact showed that the redness value of pineapple tends to decrease. The decrease in redness value was thought to be caused by the degradation of carotenoids due to oxidation reactions. The formation of hydroxyl radicals, increased pressure and temperature during the ultrasonication process could accelerate the isomerization of carotenoids from the "trans-carotenoid" form to "cis-carotenoids" which were less colorful (Rawson et al., 2011).

Table 4.2. HSD test at 5% level, the effect of interaction between ultrasonic wave frequency and contact time on the redness value (a*) of whole fresh pineapple

Treatment	*Redness* (*a**) average	HSD 5% = 1,602
A2B5 (40 kHz, 30 minute)	4,60	a
A1B2 (20 kHz, 15 minute)	5,00	a
A1B1 (20 kHz, 10 minute)	5,30	ab
A2B6 (40 kHz, 40 minute)	5,30	ab
A2B3 (40 kHz, 20 minute)	5,33	ab
A2B4 (40 kHz, 25 minute)	5,63	ab
A1B4 (20 kHz, 25 minute)	5,40	ab
A1B3 (20 kHz, 20 minute)	5,70	ab
A1B5 (20 kHz, 30 minute)	5,77	ab
A1B6 (20 kHz, 40 minute)	5,87	ab
A2B2 (40 kHz, 15 minute)	6,03	ab
A2B1 (40 kHz, 10 minute)	6,67	b

Description: Numbers followed by the same letter in the same column indicate that the treatment was not significantly different at the 5% level.

4.1.1.3. *Yellowness (b*)*

Yellowness (b*) is a chromatic color spectrum that produces yellow to blue colors with a positive notation for yellow and a negative notation for blue (Mendoza et al., 2007). The results showed that the yellowness (b*) of pineapples after ultrasonication treatment ranged from 13.47 to 17.83, while the yellowness (b*) of whole fresh pineapples without ultrasonication (control) was 15.40. The average yellowness (b*) value with the treatment of ultrasonic wave frequency and contact time can be seen in Figure 4.3.

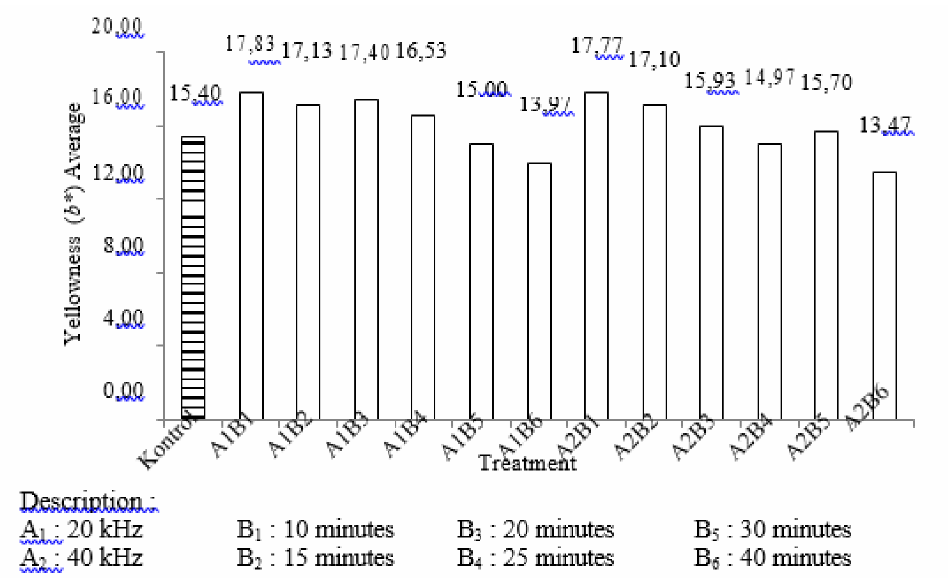


Figure 4.3. The yellowness value (b*) of the average whole fresh pineapple

The results of the analysis of variance (Appendix 6) showed that the length of contact (factor B) had a significant effect on the yellowness value, while the frequency of ultrasonic waves (factor A) and the interaction between the two treatment factors had no significant effect on the yellowness value of whole fresh pineapple after ultrasonication. Thus, a further test of Honest Significant Difference (HSD) level was carried out 5% effect of contact time on the yellowness value (b*) of whole fresh pineapple which can be seen in Table 4.3.

Table 4.3. HSD test at 5% level the effect of contact time on the yellowness value (b*) of whole fresh pineapple

Contact time	*Yellowness (b*)* average	HSD 5% = 2,536
B6 (40 minute)	13,72	a
B5 (30 minute)	15,35	ab
B4 (25 minute)	15,75	ab
B3 (20 minute)	16,67	b
B2 (15 mneit)	17,12	b
B1 (10 minute)	17,80	b

Description: Numbers followed by the same letter in the same column indicate that the treatment was not significantly different at the 5% level.

The results of the 5% HSD test (Table 4.3.) showed that treatment B6 (40 minutes) was significantly different from other treatments. The longer the contact between the ultrasonic sound wave and the pineapple, the lower the yellowness value. The results of this study were in line with Santhirasegaram et al. (2013) which stated that the yellowness value of mango juice with ultrasonication treatment (frequency 40 kHz for 15, 30 and 60 minutes) would decrease along with the longer ultrasonication time used.. The decrease in the yellowness value was thought to occur because the longer the contact between the ultrasonic waves and the pineapple the higher the temperature (28°C-37°C) and the pressure during the ultrasonication process would be quite significantly. This thing could accelerate the isomerization of carotenoids, causing carotenoids to be degraded (Chen et al. al., 1995 in Tiwari et al., 2008).

4.1.1.4. Total Color Difference (ΔE*)

The total color difference (ΔE*) shows the overall color difference between the samples that have been treated with ultrasonication and those without (control). The value of total color difference (ΔE*) can be classified as no visible color difference (0-0.5), slight color difference (0.5-1.5), visible color difference (1.5-3.0), the color difference is well visible (3.0-6.0) and the color difference is very large with the control sample (6.0-12.0) (Cserhalmi et al., 2006). The results showed that the average total color difference (ΔE*) of whole fresh pineapple ranged from 3.76 to 11.50. The average total color difference (ΔE*) of whole fresh pineapple is presented in Figure 4.4.

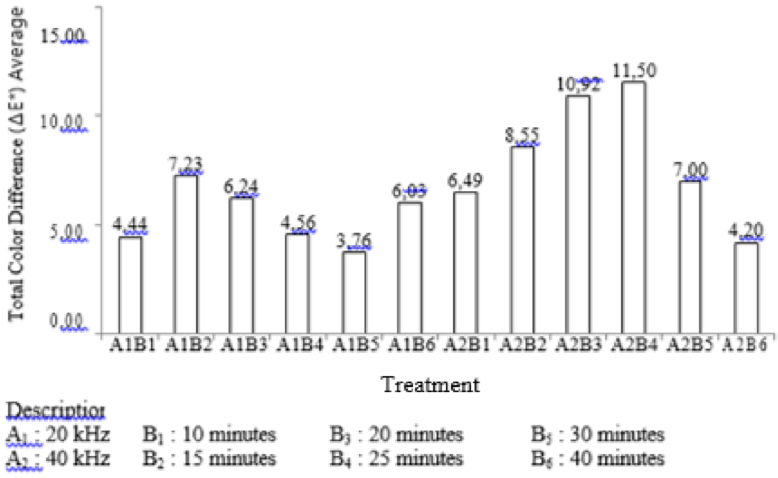


Figure 4.4. The value of total color difference (ΔE*) on average whole fresh pineapple

The results of the analysis of variance (Appendix 7) showed that the frequency of ultrasonic waves (factor A), contact time (factor B) and the interaction between the two treatment factors had no significant effect on the total color difference (ΔE*) of whole fresh pineapple. Based on Figure 4.4, it can be seen that the whole fresh pineapple fruit with ultrasonication treatment overall had an E value which was included in the category of "well visible color difference" to "very large color difference with the control sample". This indicated that carotenoid degradation occured during the ultrasonication process. Tiwari et al. (2008) stated that the degradation of carotenoids was related to the occurrence of oxidation reactions (interaction with hydroxyl radicals) and browning reactions due to cavitation energy during the ultrasonication process.

4.1.2. Texture on hardness

Hardness is an indicator that plays an important role in determining the quality of the fruit. Hardness in fruit is related to the physical structure of the tissue including cell size, shape, cell wall strength and adhesion between cells (Toivonen and Brummell, 2008). The results showed that the average hardness value of pineapple after ultrasonication treatment ranged from 30.18 gf to 38.22 gf, while the hardness value of whole fresh pineapple without ultrasonication (control) was 39.70 gf. The average hardness value of whole fresh pineapple with ultrasonic wave frequency treatment and contact time can be seen in Figure 4.5.

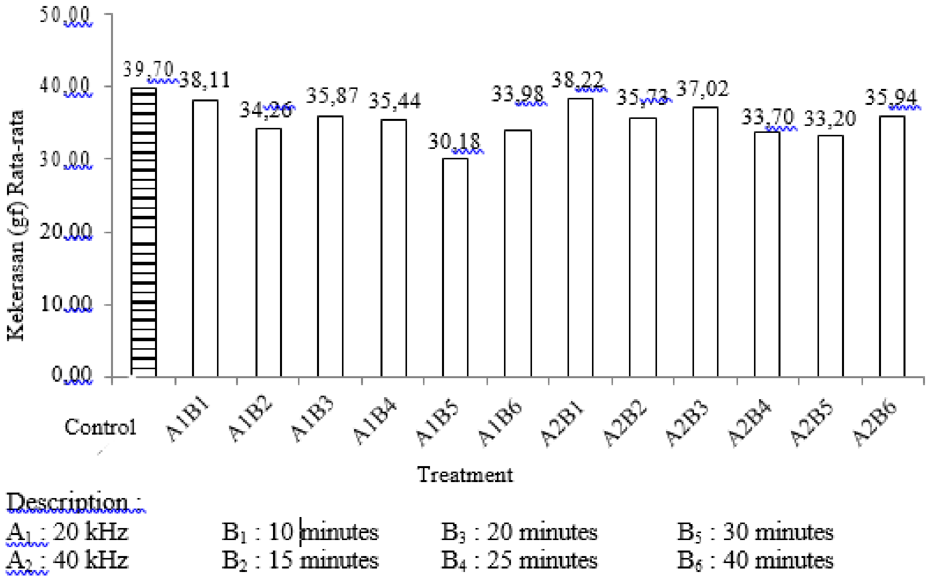


Figure 4.5. Hardness (gf) of whole fresh pineapple

The results of the analysis of variance (Appendix 8) showed that the frequency of ultrasonic waves (factor A), the length of contact (factor B) and the interaction between the two treatment factors had no significant effect on the hardness of whole fresh pineapples after ultrasonication. Based on Figure 4.5, it could be seen that the whole fresh pineapple after ultrasonication treatment had a lower hardness value than the pineapple without ultrasonication treatment (control). This showed that the cavitation energy generated during ultrasonication was capable of causing a destructive effect, namely by affecting the stability of the cell wall so that the cell become damaged and the components in the cell will come out; as the result, the hardness value of the pineapple would decrease (Fernandes et al., 2009; Aday et al. , 2013).

4.2. Chemical Characteristics of Whole Fresh Pineapple

4.2.1. Total Sugar Level

Total sugar content is the amount of carbohydrates contained in an ingredient (Marlida et al., 2014). The total sugar contained in fruit consists of simple sugars in the form of monosaccharides (glucose and fructose), disaccharides (sucrose) and sugar alcohol (sorbitol). Total sugar content in fruit can affect the sweet taste of fruit (Hoerudin, 2012). The higher the total sugar content, the sweeter the fruit taste. The results showed that in the average total sugar content after ultrasonication treatment ranged from 10.87%°brix to 14.90%° brix, while the total sugar content of whole fresh pineapple without ultrasonication treatment (control) was 15.20%° brix. The average total sugar content of whole fresh pineapple with ultrasonic wave frequency treatment and contact time can be seen in Figure 4.6.

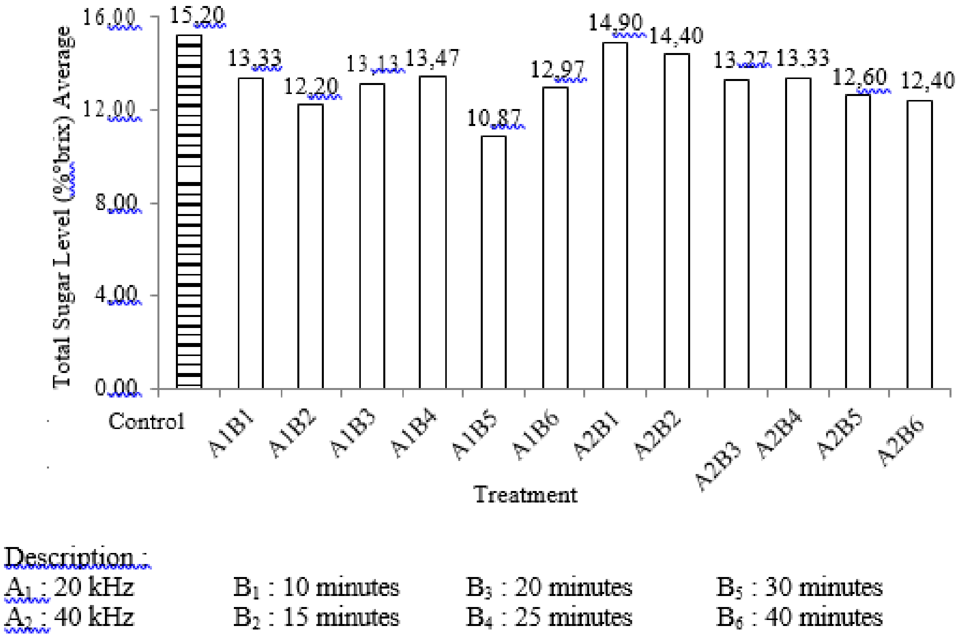


Figure 4.6. Average total sugar content (%°brix) of whole fresh pineapple

The results of the analysis of variance (Appendix 9) showed that the frequency of ultrasonic waves (factor A), contact time (factor B) and the interaction between the two treatment factors had no significant effect on the total sugar content of whole fresh pineapple after ultrasonication. Based on Figure 4.6. it can be seen that the total sugar content of whole fresh pineapple after treatment is lower than that of whole fresh pineapple without treatment (control) and tended to decrease with the longer ultrasonication time. However, the results of the analysis of variance (Appendix 9) showed that the decrease in total sugar content did not occur significantly. This is presumably, because the pineapple fruit used in this study was intact causing the intensity of the ultrasonic waves not to penetrate maximally into the flesh of the fruit.

Cravotto and Binello (2016) reported that reducing fruit size could increase the effectiveness of ultrasonic waves to reach all parts of the fruit so that it can maximally extract components in cells. The decrease in total sugar content of pineapple after treatment occurred due to the transfer of sugar components from the cell vacuole in the fruit to the liquid medium and the transfer of water from the liquid medium into the fruit. The mass transfer of sugar and water occured because of the explosion of gas bubbles and the pressure generated by the acoustic cavitation phenomenon that was able to vibrate the cells so that the cells were damaged or ruptured (Fernandes et al., 2008).

Ultrasonic waves were able to increase the process of transferring sugar from fruit to liquid medium so that the decrease in sugar content in fruit would be even greater. This is in accordance with the research conducted by Fernandes et al. (2008) who compared pineapples that were only soaked in water with pineapples that were soaked in water and treated with ultrasonication. The results showed that the percentage reduction in total sugar content of pineapples treated with ultrasonication was greater (21.7%) with a shorter time (10 minutes) than pineapples that were only soaked in water (21.3% for 30 minutes).

4.2.2. pH

pH or degree of acidity indicates the level of acidity or alkalinity of a material. A material is acidic if it has a pH value < 7, alkaline if it has a pH value > 7, and normal with a pH value of 7 generally have an acidic pH (pH < 7) (Angelia, 2017). The pH value of the fruit is influenced by the content of organic acids contained in the fruit (Astuti and Pade, 2020). The results showed that the average pH value of whole fresh pineapple after ultrasonication treatment ranged from 3.43 to 3.90, while the pH value of whole fresh pineapple without ultrasonication treatment (control) was 3.63. The average pH value of whole fresh pineapple with ultrasonic wave frequency treatment and contact time is presented in Figure 4.7.

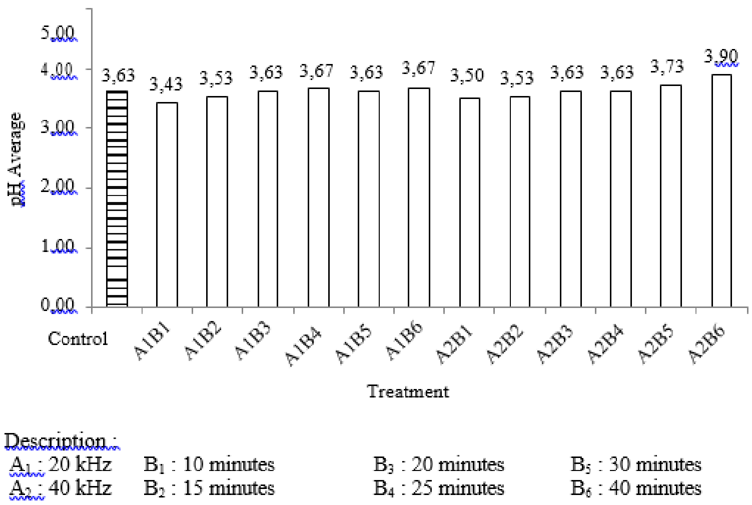


Figure 4.7. Average pH of whole fresh pineapple

The results of the analysis of variance (Appendix 10) showed that the length of contact (factor B) had a significant effect on the pH value, while the frequency of ultrasonic waves (factor A) and the interaction between the two treatment factors had no significant effect on the pH value of whole fresh pineapple after ultrasonication. Thus, a further test of the Honest Significant Difference (HSD) was carried out at a level of 5% the effect of contact time on the pH value of whole fresh pineapple which can be seen in Table 4.4.

Table 4.4. HSD test 5% level the effect of contact time on the pH value of whole fresh pineapple

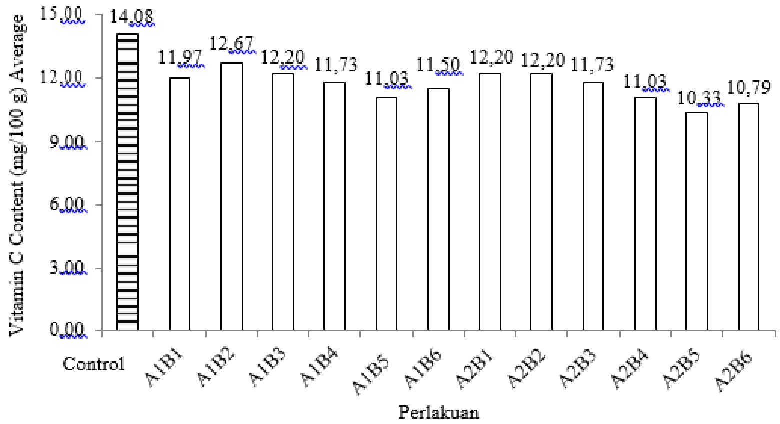
Contact time	pH average	HSD 5% = 0,2592
B1 (10 minute)	3,47	a
B2 (15 minute)	3,53	ab
B3 (20 minute)	3,63	ab
B4 (25 minute)	3,65	ab
B5 (30 minute)	3,68	ab
B6 (40 minute)	3,78	b

Description: Numbers followed by the same letter in the same column indicate that the treatment was not significantly different at the 5% level.

The results of the 5% HSD test (Table 4.4.) showed that treatment B1 (10 minutes) was significantly different from treatment B6 (40 minutes) but not significantly different from other treatments. The longer the contact that occurs between the ultrasonic waves and the pineapple, the higher the pH value of the pineapple would be. The more gas bubbles that were formed due to a longer contact, the more cavitation energy could increase which resulted in cell damage (vacuoles). Organic acids contained in pineapples such as citric acid, malic acid and oxalic acid which were water soluble would come out as a result of damaged cells (vacuoles) (Ashokkumar, 2015). Figure 4.7 showed that the pH value of pineapple after treatment tended to increase. This was in accordance with the research of Muzzaffar et al. (2016) which stated that the pH value of cherries increased after being treated with ultrasonication (frequency 33 kHz for 0, 10, 20, 30 and 40 minutes). The ultrasonication treatment was thought to be able to interfere with fruit metabolism processes which resulted in a decrease in the decomposition process of organic acids as one of the components stored in cells (vacuoles) (Muzaffar et al., 2016). In addition, ultrasonication was thought to inactivate enzymes involved in organic acid decomposition (Sao-Jose et al., 2014).

4.2.3. Vitamin C Content

Vitamin C is one of the vitamins contained in pineapples. According to Hossain et al. (2015) pineapple fruit contains 24 mg of vitamin C per 100 g of fruit. Vitamin C in fruit is often referred to as fresh food vitamine because fresh fruit has higher levels of vitamin C when compared to fruit that has been processed (Putri and Setiawati, 2015; Kurniawati and Riandini, 2019). The results showed that fresh whole pineapple after ultrasonication treatment contained an average of 10.33 mg/100g of vitamin C to 12.67 mg/100g, while the vitamin C content of pineapple without ultrasonication treatment (control) was 14.08 mg. /100g. The average vitamin C content of whole fresh pineapple with ultrasonic wave frequency treatment and contact time can be seen in Figure 4.8.



Description :
A_1 : 20 kHz B_1 : 10 minutes B_3 : 20 minutes B_5 : 30 minutes
A_2 : 40 kHz B_2 : 15 minutes B_4 : 25 minutes B_6 : 40 minutes

Figure 4.8. The average vitamin C content (mg/100 g) of whole fresh pineapple

The results of the analysis of variance (Appendix 11) showed that the frequency of ultrasonic waves (fThe average vitamin C content (mg/100 g) of whole fresh pineapple sector A), contact time (factor B) and the interaction between the two treatment factors had no significant effect on vitamin C levels of whole fresh pineapple after ultrasonication. Based on Figure 4.8, it could be seen that the vitamin C content of pineapple tended to decrease during the ultrasonication process. This was thought to be caused by vitamin C which was easily soluble in water and easily damaged due to oxidation by light, oxygen and heat (Winarno, 2004). The results of this study were in line with the research conducted by Gani et al. (2016) which showed that the levels of vitamin C in strawberries decreased after being treated with ultrasonication (frequency 33 kHz for 10, 20 and 30 minutes) by 36.68%, 35.57% and 32.20%, respectively. A decrease in vitamin C levels after ultrasonication treatment was also reported by Cao et al. (2019) which stated that vitamin C levels in bayberry fruit juice tended to decrease during ultrasonication (20 kHz frequency for 2, 4, 6, 8 and 10 minutes) with the highest percentage loss of 19.61% indicated by bayberry juice with treatment ultrasonication for 10 minutes.

The decrease in vitamin C levels was thought to be due to the interaction of hydroxyl radicals (-OH) formed as a result of cavitation energy and an increase in temperature that occurerd during ultrasonication so that it could cause vitamin C to be oxidized (Lee and Feng, 2011). In addition, cavitation energy could also cause damage to the cell wall resulting in mass transfer of components to the outside of the cell (Bhargava et al., 2021). One of the components in the cell that can move out of the cell was vitamin C because it was easily soluble in water so that the level of vitamin C in whole fresh pineapples decreased after ultrasonication treatment.

CHAPTER 5
CONCLUSIONS AND SUGGESTION

5.1. Conclusions

The conclusions obtained from the results of this study are as follows:

1. The frequency of ultrasonic waves has a significant effect on the lightness value (L*) of whole fresh pineapple, while the length of contact has a significant effect on the value of yellowness (b*) and pH of whole fresh pineapple.
2. The interaction of ultrasonic wave frequency and contact time significantly affects the redness value (a*) of whole fresh pineapple.
3. The treatment of A1B5 (ultrasonic wave frequency 20 kHz with a contact time of 30 minutes) is the best treatment based on the lowest total sugar content value of 10.87%°brix with a characteristic pH value of 3.63, vitamin C content of 11.03 mg/100 g, lightness 46.10%, redness 5.77, yellowness 15.00, total color difference 3.76 and hardness 30.18 gf.

5.2. Suggestion

Based on the results of the research that has been obtained, the author suggests that further research be carried out on the effect of fruit size, fruit maturity level and other varieties of pineapple so that comparisons can be made.

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