

IMPACT OF THERMAL TREATMENTS ON QUALITY ATTRIBUTES OF PINEAPPLE JUICE

A THESIS

BY

MD ASADUZZAMAN

Student Id: 1607029

Session: 2023-2024

Semester: Jan-Jun (2024)

MASTER OF SCIENCE

IN

FOOD PROCESSING AND PRESERVATION



**DEPARTMENT OF FOOD PROCESSING AND PRESERVATION
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY
UNIVERSITY, DINAJPUR-5200**

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ABSTRACT

Pineapple (*Ananas comosus*) fruit juice is a popular beverage known for its alluring flavor, aroma, and nutrients, including organic acids, minerals, fibers, and proteins, which may help reduce the risk of chronic diseases. However, its highly perishable nature is a cause for great concern. This study compared the effects of thermal processing, specifically microwave and autoclave treatments, on physicochemical parameters, bioactive components, antidiabetic activity, vitamin C and antioxidant capacity of pineapple juice. Additionally, the study evaluated changes in endogenous enzymes such as polyphenol oxidase (PPO) and peroxidase (POD), microbial counts, and sensory qualities of juice during 28 days of storage at room temperature. The study indicated that the pH, total soluble solids (TSS), titratable acidity (TA), and antidiabetic activity of both microwave- and autoclave-treated juice exhibited no significant change. However, there were noticeable changes in the overall color difference (ΔE), bioactive components, vitamin C, and antioxidant capacity compared to fresh juice. It was found that microwave treatment resulted in higher retention of overall color difference (ΔE), total phenolic content (TPC), total flavonoid content (TFC), vitamin C, and antioxidant capacity compared to autoclave treatment. Furthermore, polyphenol oxidase, and total microbial count of juice were inactivated below the detection limits after microwave treatment, but peroxidase had some residual activity. However, the total microbial count and PPO activity showed an increasing trend during storage, while the POD activity remained constant. Overall, these results demonstrated that microwave could be an effective replacement to other conventional thermal processing for production of high-quality pineapple juice.

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CHAPTER I

INTRODUCTION

Pineapple (*Ananas comosus*) is a popular tropical and subtropical non-citrus fruits (Ali et al., 2020) native to Argentina, Brazil, and Paraguay (Zheng et al., 2012). Pineapple's popularity is based on its appealing flavor and aroma characteristics (Paniagua-Martínez et al., 2018), as well as its therapeutic components, which play a crucial role in reducing the threat of chronic diseases (Laorko et al., 2013). Pineapple is considered an ideal fruit for the human body to get nutrients because it is high in organic acids, various minerals, dietary fibers, and proteins (Hossain et al., 2015; Ali et al., 2020; Ghafari & Ansari. 2018). Furthermore, pineapple contains a high concentration of bioactive components, which enhances its antioxidant capacity (Ferreira et al., 2016; Sew et al., 2014). Because of its alluring flavor, abundant nutrition, and antioxidant content, pineapple has shown increasing popularity and growing demand over the years (Wu et al., 2021). The fruit's high-water content, however, makes it highly susceptible to microbiological and physicochemical degradation, which has hindered the growth of the pineapple industry (Hounhouigan et al., 2014). Therefore, fresh pineapple fruits are typically processed into a variety of products like dried pineapple, cans, chips, juices, jams, and jellies to extend their shelf life. Among these items, pineapple juice is the most prominent pineapple commodity, despite its limited shelf life (Abraham et al., 2023; Khalid et al., 2016; Hounhouigan et al., 2014). As a consequence, steps must be taken to increase its shelf life.

Physical treatments, such as thermal and non-thermal methods, are mostly employed to extend the shelf life of fruit juice because they inactivate both enzymes and microorganisms (Goh et al., 2012; Leneveu-Jenvrin et al., 2020a). Fruit juices have been processed using a variety of techniques, including high hydrostatic pressure (HHP), pulsed electric fields (PEF) ultrasonication, autoclaving, ohmic heating, microwave heating, and traditional pasteurization (Wang et al., 2017; Roobab et al., 2022; Chen et al., 2024; Saikia et al., 2016; Chua et al., 2020; Rawson et al., 2011). These novel nonthermal methods have the ability to maintain the freshness and nutritional content of pineapple juice (Jeevitha et al., 2023). But the high expense of physical treatment equipment remains a major challenge for many small and medium-sized companies. Thus, out of all the approaches, heat treatments or traditional pasteurization are obviously more economical for small-scale processing facilities, and their

potential to generate high-quality juices requires more investigation (Leneveu-Jenvrin et al., 2020b).

Microwaves, which produce electromagnetic radiation, are frequently used in the agricultural and food processing industries for drying and heating purposes (Guzik et al., 2022). This process involves moisture migration and heat transfer from the food's core to its surface when microwaves penetrate through the air and partially convert to thermal energy for heating (Zhao et al., 2019). Microwave or dielectric energy offers several benefits, including deeper penetration into solid materials, selective absorption by water molecules, and rapid enzyme inactivation in fruit juice (Assawarachan et al., 2011). However, microwave energy may have some effects on food quality due to the heat produced within food materials and the influence highly depends on the microwave power, heating duration, sample size, and composition, particularly the water content (Chua et al., 2020). The quick heating and shorter heat exposure time help minimize the loss of organoleptic quality and reduce the degradation of heat-sensitive nutrients and bioactive components (Saikia et al., 2016).

Autoclaving is another heat treatment method used in juice processing that employs high temperatures and pressure to improve sterilization and extend shelf life. Although some research has been conducted on using autoclaves for various juice preparations (Chen et al., 2024; Chen et al., 2015), pineapple juice by autoclaving has not been extensively studied.

Objectives

The aims of present study were to

- compare the effects of microwave and autoclave treatments on physical properties, quality bioactive compounds, sensory attributes of pineapple juice,
- assess the effectiveness of microwave treatment in preserving pineapple juice during storage at room temperature.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Pineapple (*Ananas comosus*) is a tropical fruit widely cultivated in South America which can either be consumed fresh or processed into various food products. It is ranked third in production of tropical fruit after banana and citrus. The pineapple market has been growing extensively due to the attractive aroma compounds and nutritional values as well as huge demand and competitive retail prices (Abu Bakar et al., 2013; Martínez et al., 2012). Pineapple is mainly cultivated in the tropical and subtropical regions due to the temperate climate and rainfall distribution (Shamsudin et al., 2020). The shelf life of pineapple can be prolonged by storing the fruit under specific conditions and storage temperature as well as specific treatments to avoid microorganism contamination (Ismail et al., 2018). In this context, a well-reasoned anticipation is to transform perishable fruits into staple products with a longer shelf life has been developed to reduce the qualitative quality deterioration of the fruit during storage.

In recent years, pineapple has gained much attention since the nutritional composition has contributed to the potential uses as functional food and various pineapple-based products. Based on the physicochemical composition and nutritional values, pineapple can be considered as one of the most useful fruits for manufacturing value-added compounds such as antioxidants, organic acids, bromelain, and phenolic compounds. The typical bioactive compounds of pineapple are mainly phenolic compounds and flavonoids that are present in the morphological parts of the fruit (Lobo et al., 2016). The health aspects involving the nutrient attributes of pineapple are the main consideration in developing the food-based and waste processing products. By taking advantage of the complete utilization of pineapple, the potential for profitable goods either in the food industries and other sectors could provide a wide variety of food-based and waste processing products with high economic importance.

2.2 Pineapple physiology and characteristics

To date, there are many pineapple varieties with various colors, shapes, sizes, and flavors. Pineapple is a rather medium size compared to other tropical fruits which consist of multiple fruitlets with a distinctive maturation pattern from the top part near the crown until the bottom part of the fruit (Montero et al., 2010). Considering the fact that pineapple is a non-climacteric fruit, the quality of the fruit changes and is not uniform at different maturity

levels. Typically, the maturity indicators of pineapple are evaluated based on physical, physicochemical, and chemical attributes of fruit with acceptable flavor and morphological characteristics (Hossain, 2016).

Pineapple possesses different composition values with different varieties and maturity stages of the fruit. To date, more than 100 varieties of pineapple exist in which only 6 to 8 varieties are grown commercially (Steingass et al., 2020). The main variety is Smooth Cayenne, comprising more than 70% of pineapple cultivated around the world. Recently, it has been substituted by the successful hybrid of MD2 which was produced from the hybridization of Smooth Cayenne. The MD2 variety has high sugar content, longer lifespan, and is more aromatic compared to other pineapple varieties (Hossain, 2016). In addition, Morris is derived from the Queen variety which has a high tolerance to pest and diseases compared to other pineapple varieties (Siti et al., 2019). In contrast, N36 is derived from a breeding process between Smooth Cayenne and Spanish varieties which has high resistance to pests and diseases and a longer shelf life (Siti et al., 2013).

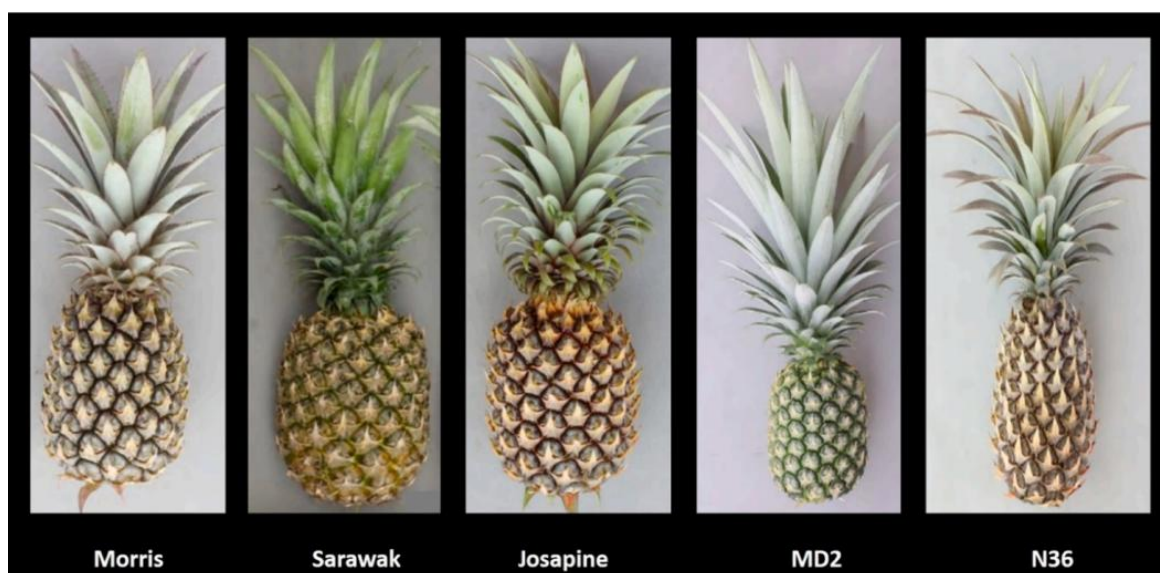


Figure 1: Different varieties of pineapples

For this variety, the pineapple flesh is suitable for the canning processed fruits. The main factors for the external quality of pineapple are determined based on the size, appearance, aroma, and skin colour. Figure 1 shows the main pineapple varieties at different varietal groups.

2.3 Physicochemical composition and nutritional values

The increasing trend in pineapple production in the commercial line has been recognized due to its high concentration of phytochemical composition, nutritive potential, and the functional properties of the fruit. This scenario has led to advancement towards exploring the nutritional value as well as the physicochemical composition of pineapples. The exceptional feature of abundant nutrients and chemical composition are of interest to the food processing industries. This section discusses valuable information related to the physicochemical composition and nutritional value of pineapples as a major tropical fruit of the world.

2.3.1 Physicochemical composition

The physicochemical composition is vital because of the potential effect on the quality and shelf life of different types of varieties of pineapples. The physicochemical composition of pineapple is closely correlated to the sensory attributes such as aroma (volatile compounds) and taste (Ancos et al., 2016). In this regard, the important properties to predict physicochemical composition apart from the sensory attributes are titratable acidity, total soluble solids (TSS), pH, moisture content, firmness, and translucency of the fruit pulp. Colour is a significant parameter in fruits because the consumers are prone to evaluate the specific product based on the visual appearance (Sanchez et al., 2012).

George et al. (2016) investigated the changes of Sarawak pineapple flesh based on the firmness, TSS, pH, and titratable acidity from one to five months after anthesis. The firmness and pH values reduced whereas the TSS and titratable acidity values increased during the fruit development. Siti et al. (2019) studied the relationship between the physicochemical properties including colour changes, pH, and TSS of three different pineapple varieties (Morris, MD2, and N36) and consumer acceptability. The results demonstrated that different pineapple varieties possess different compositions which result in significant variation in terms of consumer acceptability. Recently, Dolhaji et al. (2019) reported the effect of storage time on the TSS and pH of three different pineapple varieties stored at a sub-optimal temperature of 4 °C for 28 days. Based on the findings, the quality parameters deteriorated with storage days due to the physical injuries that were associated with quality degradation when exposed to cold temperatures. Shamsudin et al. (2020) investigated the physicochemical properties of Josophine pineapples including TSS, pH, and titratable acidity stored at 4 °C for 25 days. The results indicated that the physicochemical properties of pineapple were correlated well with the ripening process of the fruit.

2.3.2 Nutritional values

Pineapple primarily contains carbohydrates and water which are vital sources of dietary fibre, sugars, organic acids, vitamins (ascorbic acid, niacin, and thiamin), and minerals (magnesium, manganese, and copper) (Ancos et al., 2016). Pineapple fruit also contains a proteolytic enzyme namely bromelain which assists in the digestion process as well as being essential for the therapeutic effects associated with bromelain. Bromelain has various potential uses as an anti-inflammatory, antioxidant, anti-cancer activity, and cardio protective agent (Zdrojewicz et al., 2018).

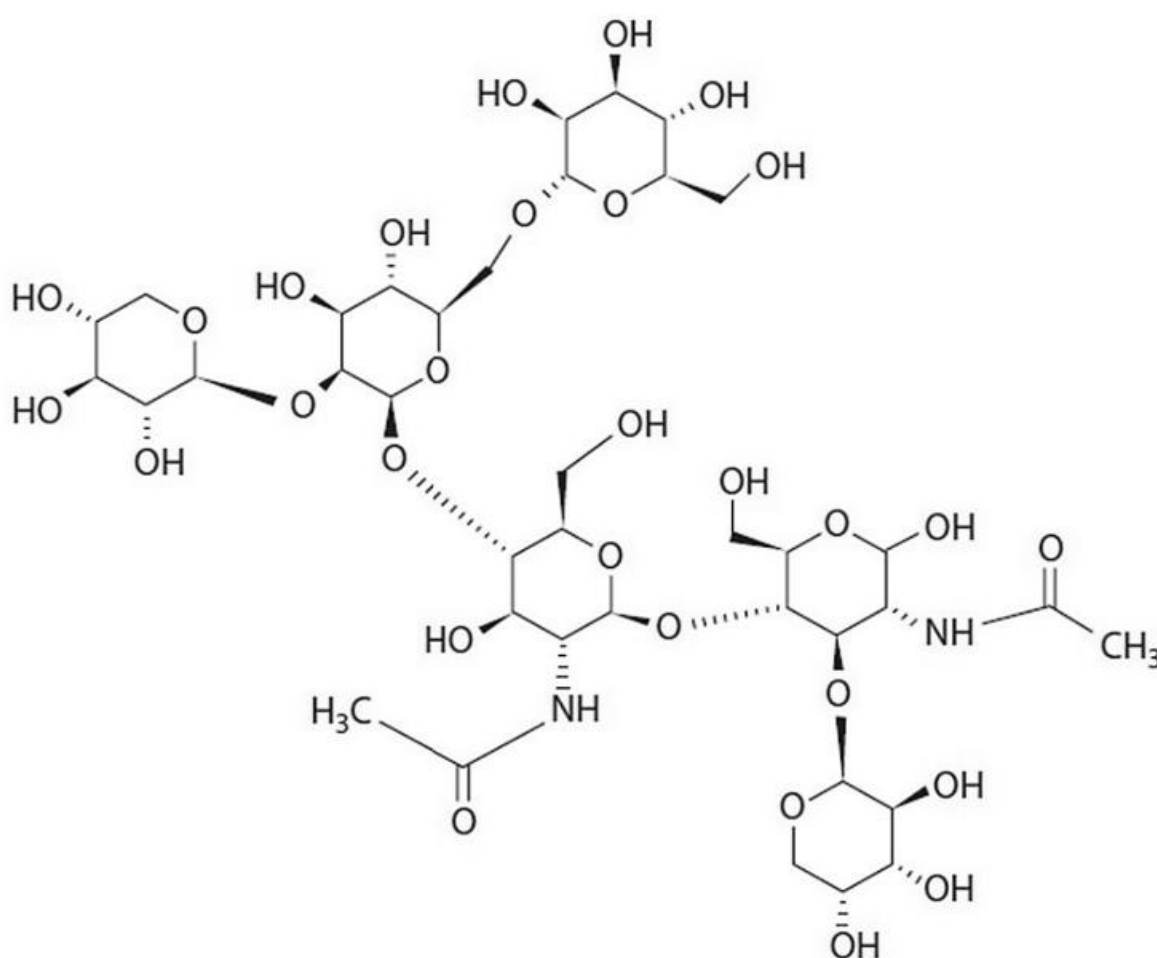


Figure 2: Chemical structure of bromelain in pineapple (Khalid et al., 2016)

In order to evaluate the need for pineapple processing, an understanding regarding the chemical composition as well as nutritional values of pineapple should be a vital indicator to monitor the quality of the fruit. The composition of pineapple is highly dependent on many factors including the ripening process and type of cultivar. Hossain et al. (2011) reported the phenolic content of pineapple comprised of methanol (51%), ethyl acetate (14%), and water

extract (3%). Similar results were obtained for the determination of antioxidant activity through a β -carotene-linoleate acid antioxidant assay at 100 ppm of concentration. Evaluation of antioxidant properties carried out by Chiet et al. (2014) reported the presence of bioactive compounds and antioxidant capacity for three different varieties of pineapples (Josapine, Morris, and Sarawak) harvested at commercial maturity stage. Josapine pineapples indicated the highest total phenolic and tannin content, followed by Morris and Sarawak. A summary of the compositional and nutritional characteristics of pineapple is shown in Table 1.

Table 1: Main constituents of pineapple (per 100 g) (Khalid et al., 2016).

Constituents	Pineapple pulp	Pineapple juice
Proximate composition		
Protein	0.5	0.4
Carbohydrate	11.7	12.1
Fat	0.5	0.1
Total sugars	10.5	12.1
Fibre	1.2	0.2
Ash	0.3	0.4
Minerals		
Calcium	8.0	8.1
Magnesium	15.0	13.6
Potassium	140.0	134.0
Iron	0.17	0.2
Manganese	0.8	1.2
Sodium	5.0	5.2
Copper	0.06	0.04
Phosphorus	8.1	9.8
Zinc	0.08	0.08
Vitamins		
Ascorbic acid	46.1	14.0
Folate	19.6	23.0
Niacin	0.3	0.3
Thiamin	0.1	0.1
Riboflavin	0.03	0.02

2.4 Potential food of pineapples

A large amount of pineapple flesh or pulp is normally used in various food-based products after peeling the skin and removing the central core. The flesh contained a high concentration of vitamins, minerals, fibre, as well as other chemical attributes that are essential for human consumption (Barretto et al., 2013). The pineapple is mainly consumed fresh, canned, minimally processed fruit as well as flavoring due to its sweet taste and aroma. Apart from

that, a wide range of processed pineapple products are available in the commercial market including pineapple juice, dried and frozen pineapple, nectar, and canned pineapple (Khalid et al., 2016; Othman et al., 2011).

The pineapple flesh is often processed in various ways such as an ingredient in cakes, puddings, pies, compotes, and garnish, especially for sweet dishes. Although pineapple is famous in dessert cuisine, pineapple also suits well in savoury dishes such as curry and meat dishes (Phoophuangpairaj et al., 2014). In terms of processed products, the potential of the fruit is transformed into various products including preservers, powder, beverages, toffees, jams, and syrups. To satisfy the demand for pineapple food-based processed products, the therapeutic, nutritive, and medicinal values of the fruit are evaluated to incorporate as a vital ingredient in the food product (Chaudhary et al., 2019).

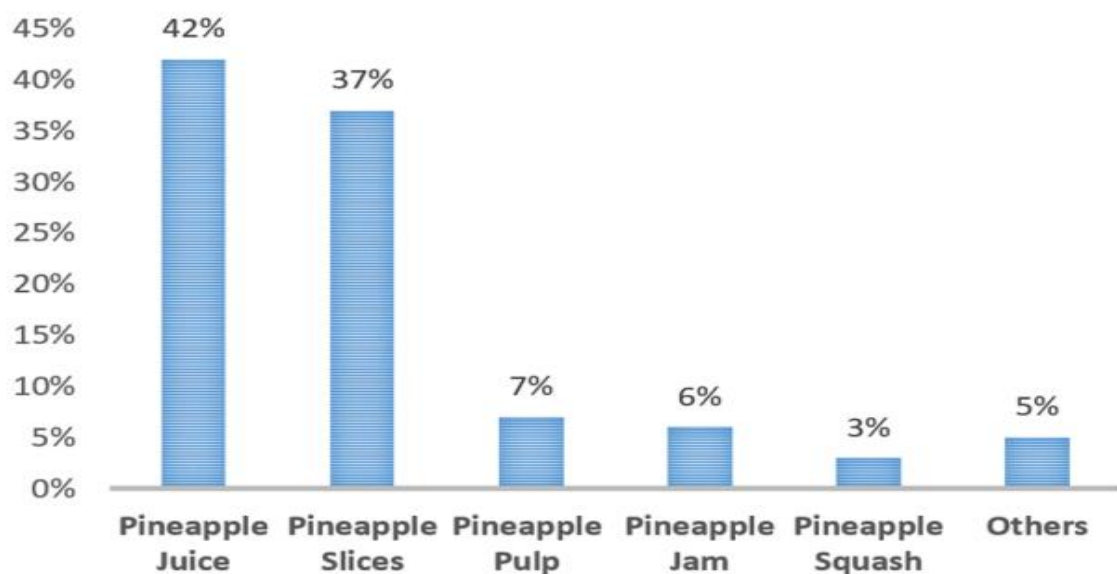


Figure 3: Percentage share of different processed pineapple products (Abraham et al., 2023).

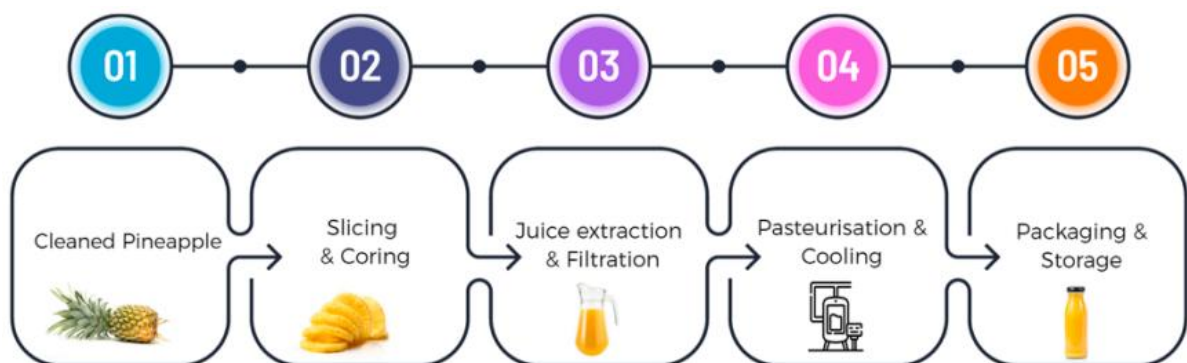
Pineapple juice is one of the processed products after being pasteurised and preserved as a juice. The microorganisms are destroyed during the juice processing due to the chemical reaction in order to optimise the processing conditions (Barretto et al., 2013). Pineapple beverages are an alternative drink processed with sugar, sweeteners, citric acid, and water according to a specific blending ratio (Siti et al., 2019). The option for low-calorie pineapple beverages can also be provided which could enhance its organoleptic qualities. Apart from this, pineapple jam is another product processed from the fruit flesh, pectin, sugar, and acid (Ismail et al., 2018).

Table 2: The potential food-based products related to pineapple

Pineapple part	Potential uses	References
Pulp	nata de pina (dessert)	(Hossain, 2016)
Young shoot	Fruit salad	(Hossain, 2016)
Young shoot	Hijos de pina (eaten raw or cooked in a savoury dish)	(Hossain, 2016)
Pulp	Dried and frozen pineapple	(Ramallo & Mascheroni, 2010)
Pulp	Cakes, puddings, pies, compotes, and garnish (sweet dishes)	(Barretto et al., 2013)
Pulp	Curry and meat dishes	(Phoophuangpairaj & Srikun, 2014)
Pulp	Preservers, nectar, toffees, jam	(Chaudhary et al., 2019)
Pulp	Juice, beverage, syrup	(Khalid et al., 2016)
Pulp	Vinegar	(Chaudhary et al., 2019)
Pulp	Wine	(Cannon & Ho, 2018)
Pulp	Powder	(Priyadarshani et al., 2019; Rahma et al., 2019)
Pulp	Canned pineapple (slices, cubes)	(Othman et al., 2011)
Peel, crown, core	Dairy feed	(Chaudhary et al., 2019)

2.5 2.5 Pineapple juice processing

Pineapple juice is among the most consumed juice and is obtained by pressing the pulp of fresh pineapple pieces. Pineapple juice is available in the form of clear juice, concentrates, and in blended form with other fruits. The composition varies according to climatic, harvest, and processing conditions. The major steps involved in the processing of pineapple juice are shown in Figure 4.

**Figure 4:** Major steps involved in the processing of pineapple juice.

2.5.1 Thermal processing by microwave

Microwave is electromagnetic radiation which is commonly used for heating and drying in food processing and agricultural industries. The wide application of microwave heating can be seen from the phenomenon that microwave oven has become a common kitchen appliance in almost every single family nowadays. It offers advantages such as rapid and volumetric heating with minimal effects on food quality (Puligundla et al., 2013). Dipolar molecules like water have a high dielectric constant, and therefore water is heated up faster than non-polar molecules. Heat is transferred from the core of food matrices to the surface in line with the direction of moisture migration (Zhao et al., 2019). The detail mechanism of microwave heating has been published by Tang (2015). Overall, microwave propagates from air to penetrate into food matrices, and partially being converted into thermal energy for food heating.

Microwave oven operates usually at relatively high frequencies ranged from the frequency of 300 MHz to 300 GHz (Fu et al, 2017) and the power of < 100-1000W (Atuonwu et al., 2019). The microwave energy may possibly affect food quality due to heat generated within food material. The impact is strongly depended on heating duration, microwave power, sample size and composition, especially water content in the sample (Datta, 2011). Dipolar molecules like water have the highest dielectric constant and vibrate stronger along with the electric field of microwave radiation. Anyhow, microwave heating is believed to have negligible impact on food quality as the heating duration is relatively short. In particular, the minimal loss of heat-labile nutrients such as vitamins and dietary antioxidants (Kalla et al., 2017).

2.5.2 Thermal processing by autoclave

Pineapple juice processing using an autoclave involves subjecting the juice to high temperature and pressure conditions to achieve effective sterilization. This method is particularly beneficial for extending the shelf life of the juice by eliminating harmful microorganisms and enzymes that could lead to spoilage. The autoclave process typically operates at temperatures around 121°C, using steam under pressure to ensure thorough heat penetration throughout the juice. Although autoclaving is commonly used in food processing for its sterilization efficiency, its application in pineapple juice processing has been less extensively studied compared to other methods.

2.6 Effect of processing on organoleptic quality of pineapple juice

A few studies have reported on the organoleptic quality of pineapple juice. Heating processes can affect the quality of a fruit juice leading to consumer dissatisfaction. Nonenzymatic browning reactions and pigment destruction have been found to be the major causes of such problems, and not enzymes causing browning because these are susceptible to heat, at temperatures of $>50^{\circ}\text{C}$ (Martinez et al., 1995). Rattanathanalerk et al. (2015) studied the effect of thermal processing on the Hunter color parameters (L, a, b, and ΔE) between 55 to 95°C . They found that with increasing temperature and time, the pineapple juice became darker, which corresponded to a decrease in L value. According to Avila and Silva, (1999) the color change was mainly due to the degradation of carotenoids and nonenzymatic browning (Maillard reaction).

The exotic flavor and aroma of pineapple are important and attractive quality attributes. Maintaining these characteristics as close as possible to the natural fresh juice is a challenge to fruit juice industries. De Vasconcelos et al. (2010) studied the changes in flavor quality of pineapple juice during processing. The study revealed that processing significantly influenced the perception of flavor and aroma in both batches, except for pineapple flavor.

2.7 Health benefits

It is well known that adequate intake of nutrients is important for human health. Pineapple has been recognized to possess valuable bioactive compounds for medical purposes. The fruit is effective as a contraceptive, a diuretic as well as for the removal of intestinal worms (Hossain, 2016). As a source of bromelain, pineapple is used by substituting proteolytic enzyme as an anti-inflammatory for soft tissue (Siow et al., 2012). Kargutkar et al. (2018) successfully investigated the potential of the anti-inflammatory activity from the pineapple leaf extract to identify the phytochemical properties that were responsible for acute inflammatory diseases.

As a potential source of dietary fibre, pineapple is effective in healing bowel movement, constipation, and gastrointestinal function (Dittakan et al., 2018). Similarly, Hossain et al. (2011) demonstrated that the functional dietary fibre in pineapple is essential in reducing the risk of diabetes, colon cancer, and cerebro-vascular diseases as well as relieving the symptoms of diarrhoea. Apart from that, it is also noted that malic acid in pineapple assists in maintaining oral health, enhancing immunity and preventing dental plaque formation (Chaudhary et al., 2019). The potential health benefits of pineapple are illustrated in Figure 4.

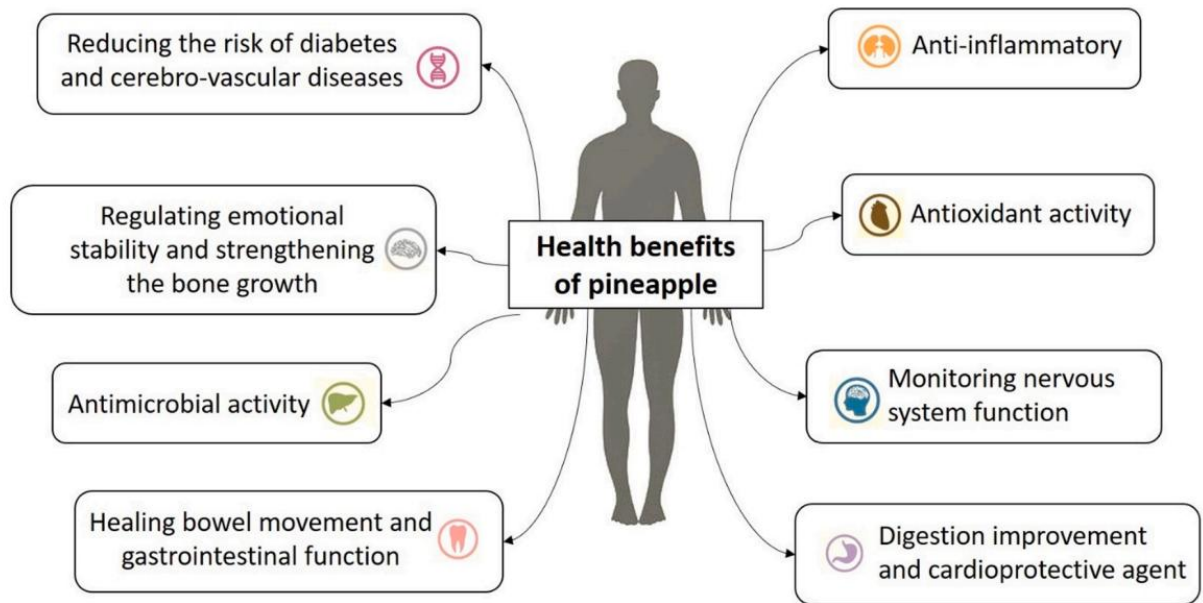


Figure 5: Potential health benefits of pineapple (Khalid et al., 2016).

CHAPTER III

MATERIALS & METHODS

3.1 Chemicals and reagents

Folin–Ciocalteu reagent, 2,2-diphenyl-1-picrylhydrazyl (DPPH), p-Nitrophenyl- α -D-glucopyranoside (pNPG), α -glucosidase, sodium bicarbonate, gallic acid, quercetin, acarbose, sodium nitrite, and aluminum chloride hexahydrate ($\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$), and methanol (99.9%), pyrocatechol, guaiacol, PVP were of analytical grade (Sigma Aldrich, Germany). Analytical grade hydrochloric acid, and sodium hydroxide, mono-sodium phosphate, disodium phosphate, potassium hydrogen phosphate (K_2HPO_4), potassium dihydrogen phosphate (KH_2PO_4), and hydrogen peroxide (H_2O_2) were also purchased from Merck, Germany.

3.2 Sample preparation

Freshly harvested, ripe, and physical damage-free pineapples (*Ananas comosus*) were collected from the fruit market in Dinajpur district, Bangladesh. The pineapple fruits were washed with tap water to remove adhering dust, peeled and removed core with a sharp stainless-steel knife. Then the flesh was cut into small pieces and the juice was extracted using a blending machine to extract the juice. The extracted juice was then filtered using cotton cloth and the collected juice was clarified in centrifuge at 4500 rpm for 20 minutes. Total soluble solid (TSS) and pH value of the juice were determined in the ranges of 12.2–14.2° Brix and 3.74–4.50, respectively. pH was modified to 4.5 by adding few drops of 5% sodium bicarbonate solution.

3.3 Thermal treatment

The juice was processed using both a microwave oven and an autoclave. To treat it in the microwave (900 watt), 400 ml of fresh juice in a 1000 ml beaker was microwaved for 6 minutes. Similarly, for autoclave treatment, the same amount of juice in a 1000 ml beaker was placed in an autoclave at 121°C and 15 psi for 10 minutes. After both treatments, the juice was immediately cooled to room temperature in a biosafety cabinet and preserved in sterilized bottle for analysis.

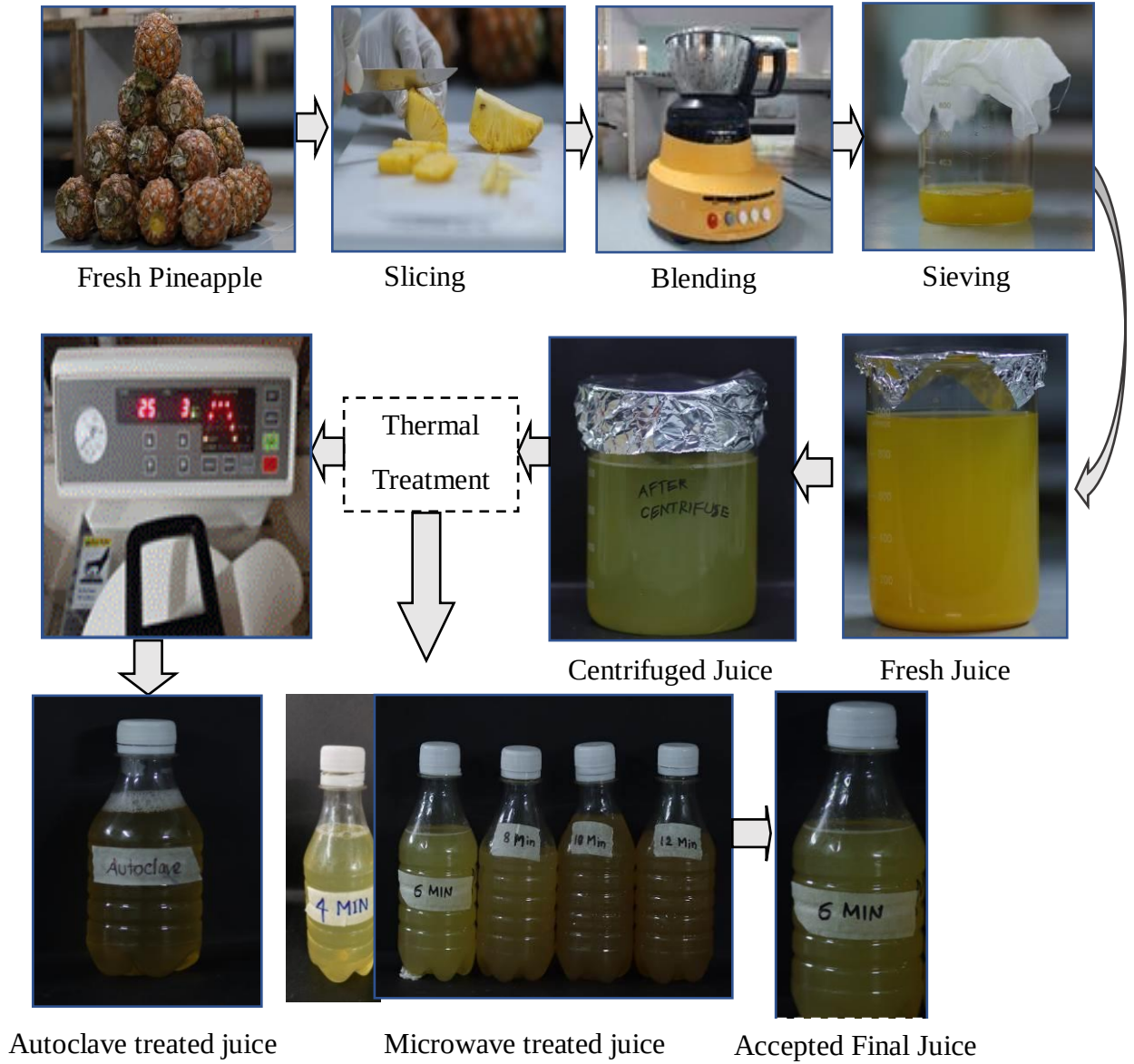


Figure 6: Steps of pineapple juice preparation

3.4 Measurements of color parameters

Color was measured by following the method described by Ma et al. (2019). A colorimeter was used to analyze color at room temperature (25°C). A white color reference was used to calibrate the chromometer. L stood for lightness, a* for redness, and b* for yellowness in the color expression system. Three measurements were taken, and the average of the data was calculated. Additionally, the following equations were used to get the overall color difference (ΔE):

$$\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2}$$

Where L_0 , a_0 , and b_0 represented the control values for raw pineapple juice.

3.5 Determinations of pH, total soluble solids (TSS) and titratable acidity (TA)

The pH values of pineapple fruit juice samples were measured at room temperature by a pH meter. The TSS of pineapple fruit juice was measured using a digital refractometer at an ambient temperature and expressed as °Brix. The TA content of pineapple fruit juice was titrated using a standardized 0.1 mol/L NaOH to the end point with phenolphthalein (pH = 8.2). The volume of consumed NaOH was expressed as citric acid equivalents in g/100 ml. Titratable acidity was calculated following the method described by Tyl et al. (2017).

$$\text{Titratable acidity (\%)} = \frac{N \times V_1 \times Eqwt}{V_2 \times 1000} \times 100$$

Where, N = normality of NaOH (mEq/ml); V_1 = volume of titrant (ml); V_2 = volume of sample (ml); Eq. wt. = Equivalent weight of citric acid (mg/mEq)

3.6 Vitamin C

Vitamin C was determined using the spectrophotometric method described by Arya et al. (1998). In summary, 10 ml of the juice sample was placed in a clean falcon tube and extracted with 10 ml of 1% metaphosphoric acid, then stored at room temperature in a dark environment. After 45 minutes, the mixture was filtered using a vacuum filter pump with 4 no. Whatman filter paper. Next, 250 µl of the filtered sample was added to a 10 ml measuring cylinder and mixed with 2.75 ml of 2,6-dichlorophenolindophenol (DCPIP). The mixture was kept in the dark for 25 minutes before measuring the absorbance at 515 nm using a spectrophotometer.

3.7 Determination of bioactive compounds

3.7.1 Total Phenol Content (TPC)

The total amount of phenolic compounds was measured using the Folin-Ciocalteu method, which was reported by Islam et al. (2023). Initially, 0.5 ml of the sample extract and 0.5 ml of the Folin-Ciocalteu reagent were mixed. 1 ml of 7.5% Na_2HCO_3 solution was transferred to the mixture, which was then diluted with distilled water to make the volume 10 ml. The mixture was vortexed for 30 seconds and then kept in a dark place for 35 minutes before it was centrifuged at 4000 rpm for 10 minutes. The absorbance was taken at 750 nm by a UV-Vis spectrophotometer (UV-1800, Shimadzu Corporation, Japan). The total amount of TPC (mg GAE/ml juice) was determined based on the gallic acid (0-200 µM) standard curve ($R^2 = 0.9976$).

3.7.2 Total flavonoids content (TFC)

The total flavonoid content (TFC) was determined following the method described by Islam et al. (2023). In brief, 1 ml of the extract was placed in a falcon tube along with 4 ml of distilled water and 0.3 mL of 5% NaNO₂ solution. After allowing the mixture to rest for five minutes, 0.3 mL of 10% AlCl₃ was added, and the solution was left to stand for one minute. Furthermore, 2.4 ml of distilled water and 2 ml of 1 M NaOH were then added and thoroughly mixed. After centrifuging the mixture for 10 minutes at 4000 rpm, it was placed in a dark area for 15 minutes. After that, a UV-vis spectrophotometer (UV-1800, Shimadzu Corporation, Kyoto, Japan) was used to measure the absorbance at 510 nm. The TFC (mg QE/ml juice) was then calculated using the quercetin (0–100 µM) calibration curve (R² = 0.993).

3.8 Analysis of antioxidant capacity

3.8.1 Antioxidant capacity measured with DPPH assay

The DPPH free radical scavenging activity was determined using the method presented by Islam et al. (2020). In brief, a vigorous mix of 50 µL juice extract and 1.950 mL of DPPH methanolic solution was used, and the mixture was allowed to rest in a dark place at room temperature. After that, a UV-vis spectrophotometer (UV-1800, Shimadzu Corporation, Japan) was used to measure the absorbance at 515 nm. The Trolox standard curve was used to determine the results, which were represented as µM Trolox equivalents per milliliter of juice (µM Trolox/ml juice).

3.9 Analysis of α -glucosidase inhibitory activity

The α -glucosidase inhibitory activity of juice extracts was measured using the method reported by Islam et al. (2020). In summary, 50 µl of each sample was combined with 100 µl of 0.1 U/ml α -glucosidase solutions (in 0.1 M, pH 6.9 phosphate buffer) and incubated for 10 minutes at 25°C. Finally, 50 µl of p-Nitrophenyl- α -D-glucopyranoside (pNPG) solution (0.1 M, pH 6.9 phosphate buffer) was mixed. After incubating the mixture for a further five minutes at 25°C, the absorbance was measured at 405 nm via a UV-VIS spectrophotometer (UV-1800, Shimadzu Corporation, Japan). The Acarbose standard curve was used to determine the results, which were represented as µM Acarbose equivalents per milliliter of juice (µM Acarbose/ml juice).

3.10 Enzyme Activity measurement

3.10.1 Polyphenol oxidase (PPO) activity

Polyphenol oxidase activity of pineapple juice was measured using the method described by Sarkar et al. (2024) with slight modification. To optimize the polyphenol oxidase assay, an enzyme extraction solution was prepared first by mixing 1% Polyvinylpyrrolidone (PVP) with 100 ml 0.02 M sodium phosphate buffer of pH 7. After that, the enzyme was extracted by adding a 10 ml juice sample to a 20 ml enzyme extraction solution and vortexed for 1 to 2 minutes. The mixture was centrifuged at 1000 rpm for 20 minutes, and the resulting supernatant was used to measure the absorbance. The final PPO assay solution comprised 2 ml of 0.1 M pyrocatechol and 0.5 ml of distilled water. The reaction was initiated by adding 500 μ L of enzyme extract to the assay solution, which was vortexed and immediately absorbance was read in a spectrophotometer at 420 nm for 15 min at 30 sec or 1-minute intervals. The polyphenol oxidase activity was calculated based on the following equation.

$$\text{Polyphenol oxidase activity} = \Delta A \times \frac{\text{Total volume}}{\text{Enzyme extract}} \times \text{Dilution factor}$$

$$\text{Dilution factor} = \frac{\text{Total volume of extraction}}{\text{Sample weight}}$$

Where, ΔA = Absorbance difference per minutes; Total volume= Cuvette reagent volume; Enzyme extract= amount of enzyme extract taken.

3.10.2 Peroxidase (POD) activity

Peroxidase enzyme activity of pineapple juice was measured using the method described by MacAdam et al. (1992) with slight modification. To optimize the peroxidase assay, enzyme extraction solution was prepared first by mixing 1% PVP with 100 ml 0.05 M potassium phosphate buffer of 6.5 pH. After that, the enzyme was extracted by adding a 10 ml juice sample to 20 ml enzyme extraction solution and vortexed for 1 to 2 minutes. The mixture was then centrifuged at 1000 rpm for 20 minutes, and the resulting supernatant was used to measure the absorbance. The final peroxidase assay solution was composed of 1 ml of 0.05 M potassium phosphate buffer (pH 6.5), 250 μ L of 0.2 M guaiacol, and 500 μ L of 0.1 M hydrogen peroxide. The reaction was initiated by adding 500 μ L of enzyme extract to the assay solution, which was vortexed and immediately absorbance was read in a spectrophotometer at 470 nm for 15 min at 30 sec or 1 minute interval. The peroxidase activity was calculated based on the following equation.

$$\text{Peroxidase activity} = \Delta A \times \frac{\text{Total volume}}{\text{Enzyme extract}} \times \text{Dilution factor}$$

$$\text{Dilution factor} = \frac{\text{Total volume of extraction}}{\text{Sample weight}}$$

Where, ΔA = Absorbance difference per minutes; Total volume = Cuvette reagent volume; Enzyme extract = amount of enzyme extract taken.

3.11 Shelf-life evaluation

After treatment, all samples were stored at room temperature for 28 days. Samples were carried out at 0, 7, 14, 21 and 28 days to determine quality and enzyme activity changes during storage.

3.12 Total Plate Count

The total plate count technique reported by Ma et al. (2019) was followed to detect live cells in pineapple juice, with some modifications. 0.89% sterile saline solution was used to serially dilute each sample, and one ml of each dilution was transferred onto triplicate plates using the nutrient agar. The total aerobic bacteria (TAB) were counted after 48 hours of incubation at 37 °C.

3.13 Sensory Evaluation

Sensory evaluation was carried out by the untrained volunteers i.e., students from Food Processing and Preservation lab, HSTU, Bangladesh. Ten evaluators were asked to rate the liking scores of the microwave treated samples from storage. The 9-point hedonic scale test, whereby 9 = like extremely much, 5 = neither like nor dislike and 1 = dislike extremely much, was applied. Before starting the evaluation, participants were instructed to rinse their mouths with drinking water every time after tasting the sample (Chaikham et al., 2016)

3.14 Statistical analysis

All results were presented as average value $\pm$ standard deviation (SD). Data was analyzed by One-way analysis of variance (ANOVA) of the SPSS 22 software (Chicago, IL, USA). Mean separations were performed by Duncan's multiple-range test. Differences were considered significant at $p < 0.05$.

CHAPTER IV

RESULT & DISCUSSION

4.1 Effect of thermal treatment on pH, TSS, and TA

As shown in Table 3, no significant ($p>0.05$) difference was evident in the TA, pH, and TSS among microwave-treated, autoclave-treated, and fresh juice samples, indicating that the microwave and autoclave had little impact on the TA, pH, and TSS of the pineapple juice. Hence, the pH (4.51–4.54), TSS (13.97–14.16 Brix) and TA (0.52–0.54%) of treated juice samples still lies within the range of standards desirable for freshly squeezed pineapple juice. Observations on non-significant deviations of pH, TSS and TA are in agreement with Wu et al. (2021) who treated pineapple juice treated thermally at 95°C for 3 min (Wu et al., 2021). Similarly, Lamo et al. (2019) reported that the sterilizing process had no significant influence on °Brix value, which was determined to be the same as guava juice (Lamo et al., 2019).

Table 3: Changes of pH, TSS, and titratable acidity in terms of thermal treatment

Sample	pH	TSS (°Brix)	Titratable acidity (%)
Fresh juice	4.50 ± 0.01 ^a	14.03 ± 0.10 ^a	0.51 ± 0.05 ^a
Microwaved	4.51 ± 0.01 ^a	14.10 ± 0.10 ^a	0.52 ± 0.02 ^a
Autoclaved	4.52 ± 0.01 ^a	14.17 ± 0.06 ^a	0.53 ± 0.03 ^a

Data are presented as means ± standard deviation (n = 3); Means followed by different superscript letters in the same column differed significantly at $P<0.05$ (ANOVA).

4.2 Effect of thermal treatment on color

The color degradation of pineapple juice as affected by thermal processing was investigated using Hunter parameters (L, a* and b*). The changes in color parameters (L, a*, b*) of microwave- and autoclave-treated pineapple fruit juices were presented in **Table 4**. A significant change ($p<0.05$) in the L*, a*, and b* values were found in the microwave and autoclave-treated juice. Compared to fresh pineapple fruit juice, both the microwave and autoclave-treated juice showed a decrease in L and b* values, while the a* value increased. Table 4 indicates that the L value of fresh pineapple juice was lighter (28.67), darkened after microwave treatment (24.97), and became darkest after autoclave treatment (22.62). The degradation in L value might be influenced by an increase in a* value and a decrease in b*

value (Rattanathanalerk et al., 2005). Similar trend was found by Rattanathanalerk et al. (2005) who reported that with increasing temperature and time, the pineapple juice became darker, which corresponded to a decrease in L value. Non-enzymatic browning (Maillard reaction) and carotenoid pigment destruction were considered as the major causes of color change in pineapple juice (Vollmer et al., 2020; Ma et al., 2019).

The ΔE value is a critical index to evaluate the color change. The ΔE value of the microwave-treated pineapple fruit juice was 4.1, while it reached 7.84 in autoclave juice, indicating that there was a significant visual difference between thermal-treated and untreated pineapple fruit juices. Yi et al. (2017) also found that a higher ΔE value was observed in apple juice after treated with thermal processing.

Table4: Changes of color parameters (L, a*, b*) in terms of thermal treatment

Sample	L	a*	b*	ΔE
Fresh juice	28.67 $\pm$ 0.11 ^a	3.07 $\pm$ 0.11 ^c	6.53 $\pm$ 0.08 ^a	-
Microwaved	23.97 $\pm$ 0.03 ^b	6.18 $\pm$ 0.01 ^b	5.07 $\pm$ 0.05 ^b	4.41 $\pm$ 0.15 ^a
Autoclaved	22.63 $\pm$ 0.05 ^c	7.29 $\pm$ 0.09 ^a	3.86 $\pm$ 0.03 ^c	7.84 $\pm$ 0.08 ^b

Data are presented as means $\pm$ standard deviation (n = 3); Means followed by different superscript letters (a-c) in the same column differed significantly at P<0.05.

4.3 Effect of thermal treatment on total phenolic content

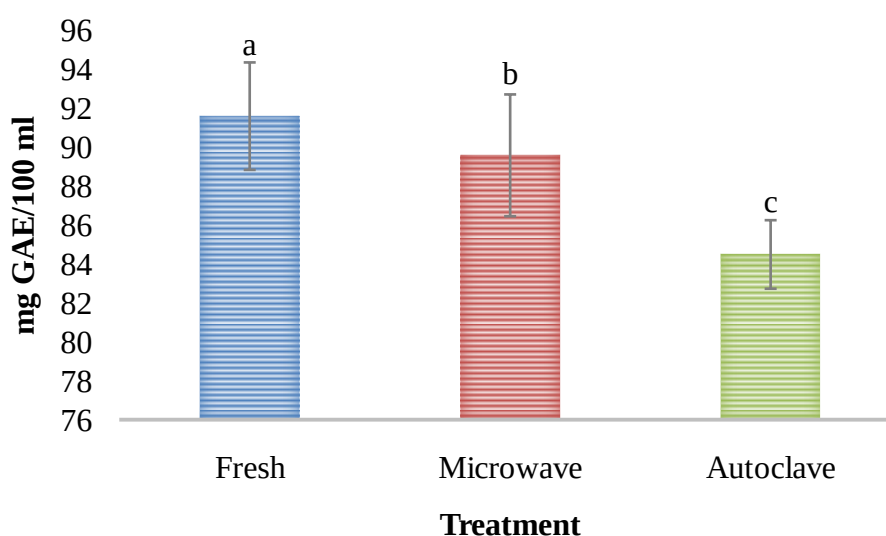


Figure 7: Changes of total phenolic content in terms of thermal treatment. Means followed by different lowercase letters (a–c) show significant differences among treatments.

Phenolics are powerful antioxidants that can protect against degenerative diseases and improve overall health (Rahman et al., 2021). The influences of microwave and autoclave treatments on the phenolic content of pineapple fruit juice were presented in Figure 7. The results of this study shows that the phenolic contents differed significantly ($p < 0.05$) among the samples. According to Figure 7, the phenolic content of the three pineapple juice samples varied from 91.57 mg GAE/100 ml to 84.83 mg GAE/100 ml, with the highest phenolic content being in fresh pineapple juice and the lowest phenolic content being in autoclaved pineapple juice. The total phenolic content of both microwave and autoclave-treated juice samples shows a reduction to 89.56 mg GAE/100 ml and 84.48 mg GAE/100 ml which are significantly lower as compared to fresh juice sample 91.57 mg GAE/100 ml ($p < 0.05$). This trend of reduction in phenolic content is supported by Chen et al. (2015). Another report by Saikia et al. (2016), who found that microwave and other thermal pasteurization negatively impacted the phenolic content (Saikia et al., 2016). The decrease of total phenolics by thermal treatment might be due to the oxidative degradation of thermally unstable phenolic compounds (Nayak et al., 2015).

4.4 Effect of thermal treatment on total flavonoid content

Flavonoids, a vital class of phytochemicals, have shown potential in combating degenerative diseases such as diabetes, cancer, inflammation, and cardiovascular disorders (Ginwala et al., 2019). The concentrations of total flavonoids in fresh, microwave- and autoclave-treated pineapple fruit juice were 9.18 ± 1.05 mg/100 ml, 7.72 ± 0.64 mg/100 ml and 7.07 ± 0.83 mg/100 ml, respectfully (Figure 8). As shown in Figure 8, a significant decrease ($p < 0.05$) was apparent in the total flavonoids of microwave- and autoclave-processed pineapple juice

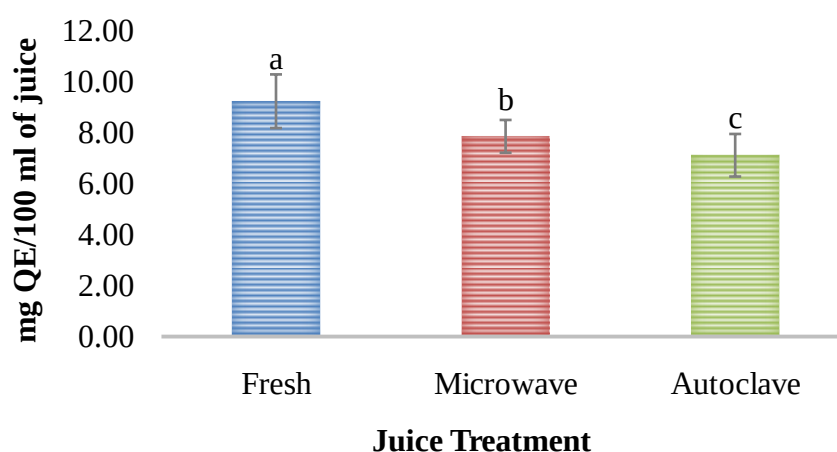


Figure 8: Changes of total flavonoid content in terms of thermal treatment. Means followed by different lowercase letters (a–c) show significant differences among treatments.

compared with the fresh juice. A reduction of 15.9% and 22.98% was found in juice samples treated with microwave for 6 min, autoclave for 15 min, respectively. The results recorded in these experiments were in agreement with previous studies (Wang et al., 2017; Saikia et al., 2016). Saikia et al. (2016) found that microwave treatment of pineapple juice reduced flavonoid content about 32%. As reported by Wang et al. (2017) thermal treatments (85 °C/15 min) significantly ($p<0.05$) reduced the total flavonoids of mulberry juice. The decrease of total flavonoids by microwave and autoclave might be attributed to the thermal instability of the phenolic compounds and flavonoid compounds (Ma et al., 2019).

4.5 Effect of thermal treatments on vitamin C

Ascorbic acid (vitamin C) is an important antioxidant that has been linked with protection against several types of cancers (Santhirasegaram et al., 2013). In this study, significant ($p<0.05$) decrease in the ascorbic acid content was observed in juice processed by microwave and autoclave treatment when compared to fresh pineapple juice **Figure 9**. A significantly ($p<0.05$) higher retention of 79% was achieved by microwave treatment for vitamin C, while it was 68% in the autoclave-treated (121°C/10 min) juice, indicating that microwave maintained higher vitamin C content than autoclave. The drastically reduce of ascorbic acid content in thermal-treated juice could be explained by the fact that ascorbic acid was critically sensitive to temperature, high temperature would aggravate the loss of ascorbic acid in juice (Wu et al., 2021). The findings obtained in this investigation were consistent with those of earlier research. According to Chen et al. (2015) autoclave-treated (121°C/3 min) asparagus juice had significantly lower ascorbic acid content (77% retention) compared with the control.

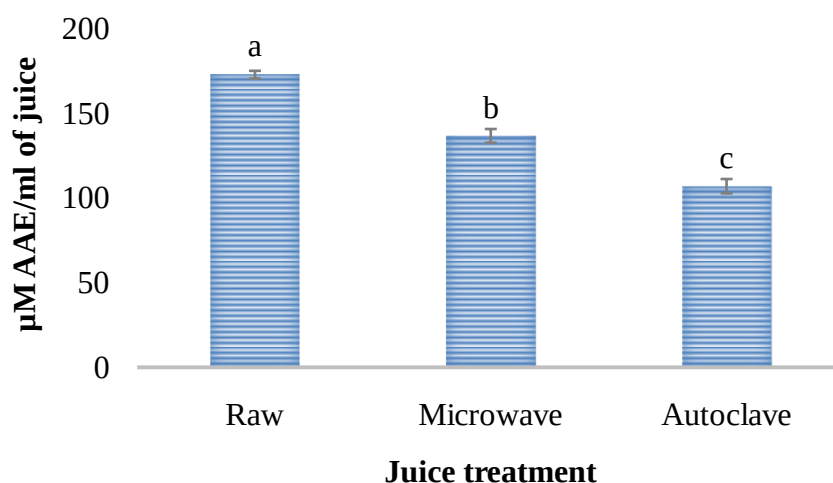


Figure 9: Changes of vitamin C in terms of thermal treatment. Means followed by different lowercase letters (a–c) show significant differences among treatments.

4.6 Effect of thermal treatment on antioxidant capacity

The influences of microwave and autoclave treatments on antioxidant capacity of pineapple fruit juice were presented in Figure 10. DPPH methods was used to measure the antioxidant capacity of pineapple fruit juice. The DPPH assay result exhibited that the antioxidant capacity of treated pineapple fruit juice was significantly ($p < 0.05$) lower than that of fresh pineapple fruit juice, and the antioxidant capacity of microwave-treated pineapple fruit juice was higher than that of autoclave treatment pineapple fruit juice. A significantly ($p < 0.05$) higher retention of 78.50% was achieved by microwave treatment for antioxidant activity, while it was 68% in the autoclave-treated sample, indicating that microwave maintained higher antioxidant activity than autoclave. The outcomes obtained in this study were consistent with the report of Chen et al. (2015) who used autoclave as thermal treatment method for Asparagus juice. The behavior of total antioxidant activity was similar to that observed for anthocyanins and total phenolic content. Therefore, the decrease in the antioxidant capacity might be attributed to the degradation of these compounds during microwave and autoclave processing (Chen et al., 2015).

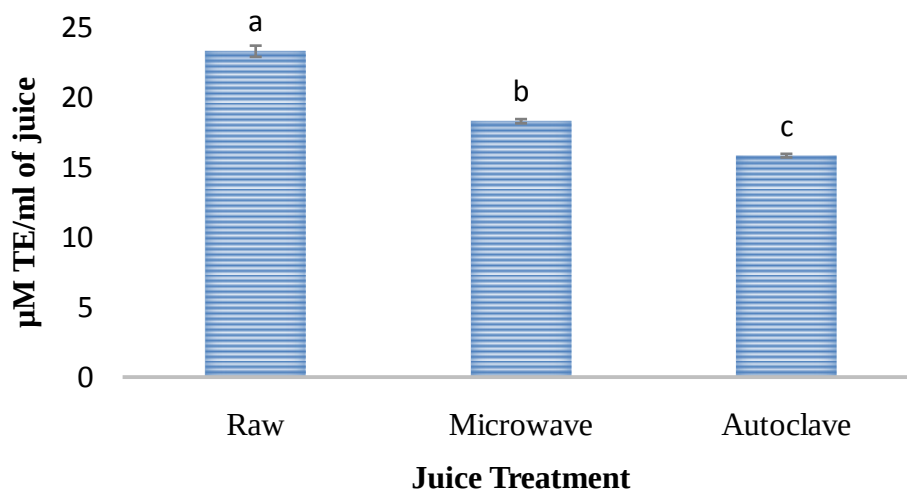


Figure 10: Changes of antioxidant capacity in terms of thermal treatment. Means followed by different lowercase letters (a–c) show significant differences among treatments.

4.7 Effect of thermal treatment on antidiabetic capacity

The primary enzyme in the small intestine that breaks down carbohydrates and converts them into glucose is called α -glucosidase, which raises postprandial glucose levels (Hasan et al., 2022). Hence, inhibitors of α -glucosidase are recommended to effectively manage type-2 diabetes by lowering glucose absorption in the blood (Kabir et al., 2021). Hence, the α -

α -glucosidase inhibitory activity of pineapple juice was investigated at different thermal treatment (microwave and autoclave) conditions to justify the effects of thermal treatment on anti-diabetic effect. The α -glucosidase inhibitory activity was 0.32 μ M AE/ml, 0.27 μ M AE/ml, and 0.29 μ M AE/ml for fresh, microwave and autoclave treated juice, respectively (Figure 11). It is found that thermal treatments did not have a significant effect ($p > 0.05$) on the α -glucosidase inhibitory activity compared to fresh pineapple juice. This result aligns with a similar study by Deshaware et al. (2019), where they pasteurized bitter gourd juice at temperatures ranging from 65-95 °C and observed no impact on α -glucosidase inhibitory activity.

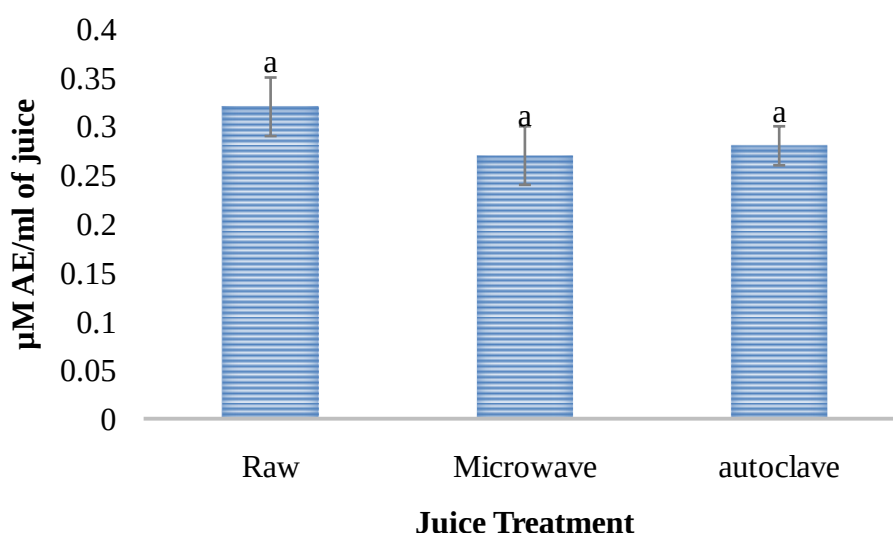


Figure 11: Changes of antidiabetic capacity in terms of thermal treatment. Means followed by different lowercase letters (a–c) show significant differences among treatments.

4.8 Shelf-life study of treated juice

The study assessed the impact of thermal treatments on the physicochemical properties and bioactive compounds of pineapple juice. The findings revealed that autoclave treatment had a greater effect on color, bioactive compounds, and antioxidant properties compared to microwave treatment. As a result, microwave-treated juice was chosen for storage evaluation over autoclave-treated juice.

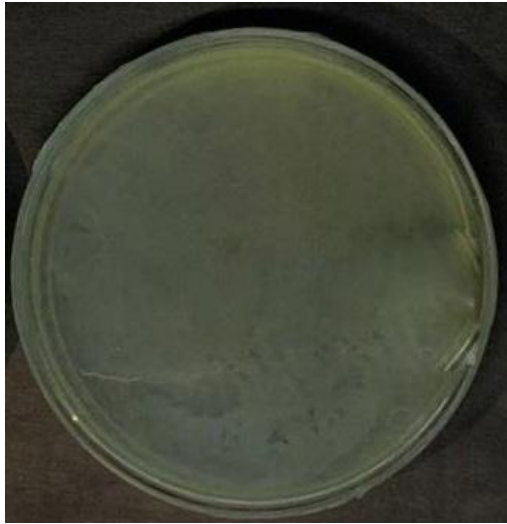
4.8.1 Effects of microwave treatment on microbial growth during storage

The microbiological quality of pineapple fruit juice was evaluated by periodically measuring the counts of TPC in pineapple fruit juice samples. The results of the total viable bacteria during the 28 days of storage at room temperature are presented in **Table 5**. After treatment with microwave, total bacterial count of pineapple fruit juice was completely inactivated (Table 5), which was consistent with previous studies (Wang et al., 2017; Vollmer et al., 2020). However, the counts of total bacteria in microwave-treated pineapple juice exhibited an upward trend during 28 days storage. According to the storage period, total bacterial count remained below the detection limit in the first two week of storage. From days 14 to 21, the microbial groups were recovered. On day 21, the total bacteria count was 5.69 log₁₀ (CFU/mL), which increased to 5.88 log₁₀ (CFU/mL) after 28 days of storage. An increased number of total bacterial count was probably attributed to the reproduction of surviving cells and the recovery of injured cells (Peñas et al., 2010). According to this result it can be said that microwave processing significantly delayed the recovery of naturally occurring microflora.

Table 5: Changes in total plate count of microwave-treated pineapple juice during storage

Days of storage	Total plate count (log ₁₀ CFU/mL)
0	N. D
7	N. D
14	5.53
21	5.69
28	5.88

Data are presented as means $\pm$ standard deviation (n = 3); N.D. not detected indicates (detection limit < 1 CFU/mL); Different superscript letters (a-c) indicate significantly different means $P < 0.05$ in the same column.



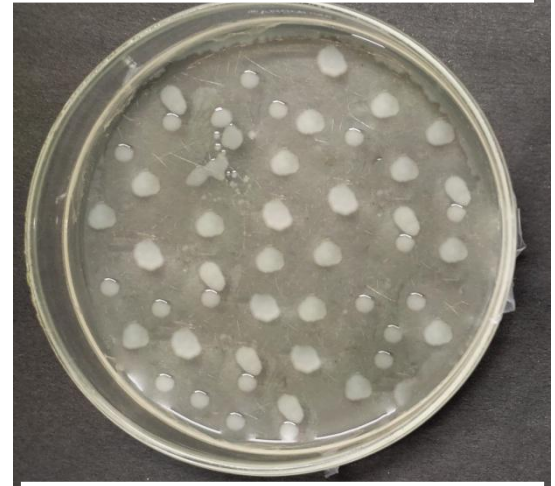
0 Days



7 Days



14 Days



21 Days



28 Days

Figure 12: Total plant count during 28 days of storage

4.8.2 Effects of microwave treatment on PPO enzyme activity during storage

The inactivation of PPO in fruit-based products is crucial to reduce quality changes and prolong shelf life (Cao et al., 2018). This study evaluated the effects of microwave treatment on polyphenol oxidase in pineapple juice during storage, and the findings are presented in Table 6. The PPO activity was entirely inactivated after a 6-minute microwave treatment. Yi et al. (2017) reported similar findings indicating that PPO activity was deactivated in cloudy apple juice after being thermally treated at 90°C. According to Table 6, PPO activity exhibited an increasing trend over the 28-day storage period at room temperature. On the 7th day of storage, polyphenol oxidase began to activate at approximately 0.08 U/ml and steadily increased, reaching 0.44 U/ml by the 28th day. The residual PPO activity increased by about 28.36% after 28 days of storage compared to fresh pineapple juice. In contrast, Swami et al. (2016) found a lower residual activity (25%) in thermally processed aloe vera-litchi mixed beverage (ALMB) during storage at 25°C.

Table 6: Changes in PPO, POD enzymes of microwave-treated juice during storage

Days	PPO (U/ml)	POD (U/ml)
0	0	0.040±0.01 ^a
7	0.081±0.1 ^c	0.049±0.01 ^a
14	0.09±0.1 ^c	0.049±0.01 ^a
21	0.126±0.1 ^b	0.054±0.01 ^a
28	0.240±0.1 ^a	0.054±0.01 ^a

Data are presented as means ± standard deviation (n = 3); Means followed by different superscript letters (a-d) in the same column differed significantly at P<0.05.

4.8.3 Effects of microwave treatment on POD enzyme activity during storage

The presence of POD activity in fruit-based products is not desirable as it leads to the oxidative reactions affecting its natural flavor and aroma (Vervoort et al., 2011). In this study, the peroxidase (POD) enzyme activity in microwave-treated pineapple juice was examined, and the changes in POD levels during storage at room temperature are presented in Table 6. The data indicate that POD was not fully inactivated by microwave treatment, with residual activity remaining at approximately 3.3% compared to fresh juice. Hirsch et al. (2008) identified POD as one of the most heat-resistant enzymes, reporting that in orange juice, its

residual activity can be reduced to 2.9–9.6% of the original level when exposed to temperatures above 62 °C (Hirsch et al., 2008). The storage study results (Table 6) indicated that there was no significant change in the POD activity throughout the 28 days of storage. This finding is consistent with previous studies. Swami et al. (2016) found that the POD activity remained constant when a thermally treated aloe vera-litchi mixed beverage was stored at room temperature for 10 to 30 days. Additionally, Hirsch et al. (2008) reported that no regeneration of POD activity was observed during storage.

Table 7: Changes in color and sensory attributes of microwave-treated juice during storage

Days	L	a*	b*	ΔE
0	24.90 $\pm$ 0.18 ^a	4.98 $\pm$ 0.19 ^c	5.06 $\pm$ 0.09 ^a	-
7	24.65 $\pm$ 0.10 ^{ab}	5.10 $\pm$ 0.11 ^c	4.93 $\pm$ 0.06 ^{ab}	0.31 $\pm$ 0.87 ^c
14	24.48 $\pm$ 0.20 ^b	5.21 $\pm$ 0.12 ^c	4.85 $\pm$ 0.07 ^b	0.51 $\pm$ 0.13 ^c
21	22.65 $\pm$ 0.16 ^c	6.15 $\pm$ 0.30 ^b	3.88 $\pm$ 0.12 ^c	2.80 $\pm$ 0.24 ^b
28	20.17 $\pm$ 0.22 ^d	7.8 $\pm$ 0.12 ^a	3.15 $\pm$ 0.11 ^d	5.82 $\pm$ 0.24 ^a

Data are presented as means $\pm$ standard deviation (n = 3); Means followed by different superscript letters (a-d) in the same column differed significantly at P<0.05 (ANOVA).

4.8.4 Effects of microwave treatment on color during storage

The effect of thermal treatment on the color parameters of fresh pineapple juice is presented in Table 7. This section now focuses on the impact of storing microwave-treated pineapple juice at room temperature. The changes in color parameters (L, a*, and b*) of microwave-treated pineapple juices during 28 days of storage in room temperature were presented in Table 7. There was no noticeable change in the color parameters of the juice that had been microwave-treated between the 0 and 7-day storage period. Based on Table 3, the L, a*, and b* values gradually changed after 14 days of storage. However, over the initial 21 days at room temperature, the ΔE value in treated pineapple fruit juice did not show significant change. Chang et al. (2016) also reported that no considerable changes were observed in TP-treated white grape juices over a 20 days storage period. On 28 days of storage, the lightness and yellowness of pineapple juice decreased from 24.97 to 20.14 and 5.06 to 3.10, respectively, while the redness increased from 4.98 to 7.58 compared to the first day of storage. However, the ΔE values of pineapple fruit juice treatment with microwave were

notably enhanced after 21 days, which may due to the increase number of microbes in pineapple fruit juice (Wu et al., 2021).

4.8.5 Effects of microwave treatment on sensory evaluation during storage

Table 8: Changes in sensory attributes of microwave-treated juice during storage

Days	Color	Flavor	Taste	Overall Acceptability
0	8.6±0.52	7.5±0.53	7.9±0.74	7.8±0.79
7	8.2±0.62	7.1±0.74	7.4±0.52	7.3±0.67
14	7.6±0.52	6.4±0.97	6.9±0.74	6.8±0.63
21	6.4±0.52	5.4±0.51	6.1±0.57	6.0±0.67
28	5.7±0.82	5.2±0.79	5.3±0.67	5.1±0.73

Data are presented as means ± standard deviation (n=10).

During the storage of microwave-treated pineapple juice, a sensory evaluation was conducted by 10 panelists using a 9-point hedonic scale. The results of the sensory evaluation are presented in Table 8. The findings indicate that all sensory characteristics (color, flavor, taste, and overall acceptability) of the stored juice were highest on day 0, with values of 8.6±0.52, 7.5±0.53, 7.9±0.74, and 7.8±0.79, respectively. These sensory parameters showed a gradual decline over the 28-day storage period, a similar trend was followed by (Swami et al., 2016). After two weeks, the scores began to drop significantly, eventually reaching the "neither like nor dislike" level by the end of the 28 days.

CHAPTER V

CONCLUSION

The study aimed to evaluate the influences of microwave and autoclave treatment on the quality characteristics of pineapple juice and to investigate the efficiency of microwave treatment on microbial safety, enzyme activity, and sensory quality of juice when stored at room temperature. Although the microwave treatment reduced some of the vitamin C, bioactive compounds, and antioxidant activity compared to fresh juice, the reduction was lower than with autoclave treatment. Some physicochemical characteristics (pH, TSS, titratable acidity) of pineapple juice remained unaffected by thermal treatments, while the total color difference exhibited a significant increase in autoclaved juice compared to microwaved juice. In addition, microwave treatment inactivated the total microbial count below the detection limit and increased during the storage period, but it remained within the acceptable limit. PPO activity exhibited an increasing trend throughout the 28 days of storage at room temperature but POD activity remained unchanged. Thus, it can be concluded that microwave treatment can inactivate enzymes and spoilage microorganisms in pineapple juice and extend shelf life for 21 days with minimal impact on quality.

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