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The Effect of Altitude on the Quality of Honey Pineapple (*Ananas comosus* (L.) Merr)

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Abstract. Pineapple (*Ananas comosus* (L.) Merr) is a plant of Bromeliaceae. Pineapple plants are widely cultivated in several countries, and Indonesia is one of the largest producers of pineapples. This study aims to determine the optimal height of the growing site for the quality of the honey pineapple. The research was carried out in the Laboratory of the Faculty of Agriculture of Swadaya Gunung Jati University in July-August 2024. Research using the Purposive Sampling method and data processing using Complete Random Design and further testing of LSD. The experimental factors used were the height of the observation location, namely 1019 m above sea level (high), 643 m above sea level (medium), and 384 m above sea level (low). The results of the study showed that altitude had a significant effect on the quality of honey pineapple fruit. The heaviest fruit weight (566.64 grams) was obtained from plants at an altitude of 643 m above sea level (medium altitude). The highest dissolved density was produced in plants at an altitude of 643 m above sea level. The highest levels of vitamin C and water content were produced in plants at an altitude of 1019 m above sea level. The highest anthocyanin content (0.01700) was obtained from plants at an altitude of 643 m above sea level, and the most extended shelf life was obtained from plants at an altitude of 384 m above sea level (lowlands).

Keywords: Altitude, Anthocyanin, Pineapple, Quality, Vitamin C

INTRODUCTION

Pineapple (*Ananas comosus* (L.) Merr) is a *Bromeliaceae* plant. Pineapple is one of the most widely consumed fruits in the world, after bananas and oranges (Wali, 2018). Pineapples are usually consumed fresh, processed or canned. Indonesia, the Philippines, Costa Rica, Brazil and China are the top five pineapple producing countries in the world (FOA, 2022). Indonesia is the world's largest pineapple producing country. However, according to data from the Food and Agriculture Organization of the United Nations, the value of Indonesian pineapple exports is still low compared to Costa Rica, which

contributed around 55% of the world's pineapple exports in 2015. The small export value of pineapples in Indonesia can be caused by the low quality of the pineapples produced.

Fruit quality is a sentence that refers to various physical, chemical and nutritional attributes that determine consumer value and satisfaction. Fruit quality can be influenced by genetics and the environment. Genetic and environmental factors can affect the differences in quality and quantity of production produced. One environmental factor that can affect the differences in quality produced is the variation in altitude.

Altitude affects the differences in plant microclimate. Microclimate can affect plants' morphological and physiological processes, which then impact decreasing or increasing the production and quality of plant yields. Microclimate, such as temperature, humidity and light intensity, are important environmental factors for plants.

LITERATURE

Increasing altitude can cause temperatures to drop, according to (Khotimah et al., 2022) every 100 meters above sea level increase in a place, the temperature will decrease by 0.61°C. Temperature can affect the rate of photosynthesis and plant respiration. High rates of photosynthesis can cause stress in plants, and respiration plays a role in the formation of energy in plants. Low respiration rates can cause low energy production and can then affect the decline in plant quality.

The higher the altitude, the higher the humidity which affects the rate of photosynthesis, respiration and transpiration. At low air humidity, plants experience a higher transpiration rate to maintain the balance of water and temperature in plant cells, and this can have a positive effect on the process of plant photosynthesis, which can improve the quality of plant production. Altitude can affect light intensity, according to (Istiawan & Kastono, 2019) Differences in altitude can affect the distribution of sunlight and the higher a place is, the lower the intensity of light that reaches the surface. The light intensity can affect the quality of fruit, such as the colour of the fruit's skin. The colour of the fruit skin can be regulated by pigments, one of which is anthocyanin. Anthocyanin is a secondary metabolite that contributes red, blue and purple colours to plants, and its levels can be affected by light (Zhu et al., 2017).

In previous research, it was discovered that altitude could affect the protein, organic acids and sugar content of walnuts (Gündeşli et al., 2023), fruit weight and vitamin C content of guava (Widyastuti et al., 2022) fruit size, fruit skin colour and fruit content of

mandarin oranges (Rokaya et al., 2016) production and quality of mango fruit (Zhang et al., 2022) flavonoid and beta carotene content of *Carica pubescens* fruit (Sholekah, 2017) in research (Artanti et al., 2016) Altitude causes variations in the distribution of light intensity, which causes the photosynthesis process to be less than perfect, affecting the levels of secondary metabolites produced by plants, thus affecting the caffeine levels in tea.

METHOD

This research was conducted in three places with different altitudes, namely Bulakan Village with an altitude of 250-450 meters above sea level (masl) (low), Beluk Village with an altitude of 500-650 masl (medium), and Gombong Village with an altitude of 1,000-1,200 masl (high). Laboratory tests were conducted at the Laboratory of the Faculty of Agriculture, Swadaya Gunung Jati University, Cirebon, West Java. The research was conducted in July - August 2024.

The study was conducted using a survey method using the Purposive Sampling sampling technique. There are two garden locations for sampling that will represent each altitude, the gardens selected to represent each altitude are gardens that have a land area above the average land area of the total gardens at each altitude.

The tools used in this study were cameras, stationery, lux meters, analytical scales, hand refractometers, thermohygrometers, penetrometers, spectrophotometers, burettes, pipettes, measuring cups, Erlenmeyer flasks, glass funnels, spatulas, knives, sieves, mortars, spirit lamps, plastic containers, tissues, mica plastic, vernier calipers and rulers.

The materials used in this study were 20 honey pineapples at each location, 0.1 N iodine, 1% amylum (cornstarch) and Aquadesh.

The parameters observed included fruit weight, fruit water content, total dissolved solids, vitamin C content, anthocyanin content, and fruit shelf life. According to (Sims & Gamon, 2002) The formula used to calculate anthocyanin levels:

$$\text{Antosianin} = (0.08137 \times A537) - (0.00697 \times A647) - (0.002228 \times A663)$$

The data obtained will be analyzed using Analysis of Variance (ANOVA) at a real level of 5% and if there are significant differences, a further LSD test will be carried out at a real level of 5%.

DISCUSSION

Fresh Fruit Weight

Fresh weight of fruit is the total weight of fruit measured immediately after harvest, before undergoing drying or further processing. According to the Dictionary of Agricultural and Food Science, fresh weight is the total weight of a material or product in a wet or undried condition, including all water content. Data from the results of the ANOVA analysis at different altitudes show that altitude significantly affects pineapple weight loss, as presented in the table below.

Table 1. Average weight of fruit with crown and weight of fruit without crown at different altitudes.

Altitude (masl)	Fruit Weight with Crown (g)	Weight of Fruit Without Crown (g)
Low (384)	542.80 b	484.04 b
Medium (643)	566.64 b	440.70 ab
High (1019)	378.12 a	293.30 a

Note: The average values between treatments in the same column followed by the same letter were not significantly different based on the 5% LSD test.

Table 1 shows that the altitude significantly differs in each pineapple treatment. The heaviest fresh weight of pineapple is seen at medium altitude, where the average fruit weight with a crown reaches 566.64 grams based on SNI Pemalang Honey Pineapple 2020, which is included in grade A, while the average fruit weight without a crown is 440.7 grams. Because of the difference in altitude, it also has a different microclimate such as temperature, light intensity and humidity. So that it can affect the process of photosynthesis and metabolism in the fruit.

The microclimate that causes differences in the weight of fresh pineapple fruit at different altitudes, one of which is temperature, at higher altitudes shows a smaller weight (Muñoz-Ordoñez et al., 2023). This is because at higher altitudes the temperature is lower, thus reducing the rate of transpiration in the fruit, resulting in the fruit ripening process being less than optimal (Istiawan & Kastono, 2019). Likewise with light intensity, at medium heights, it produces larger and heavier fruit weights. This is because fruit at medium heights gets more daily sunlight, thus supporting an efficient photosynthesis process, resulting in higher carbohydrates (Suwandi et al., 2016).

According to Sri Setia Triharjadi (2020) carbohydrates are needed to form new cells, such as flower buds, flowers, fruits, and seeds in the reproductive phase. These cells require large amounts of carbohydrates, generally in the form of starch and sugar. This

reproductive phase also involves various important processes, including the formation of hormones needed to develop flower buds and fruit formation.

Water content

Water content is the percentage of water contained in fruit, which can be a factor in fruit quality, because it can affect the appearance, texture and taste of the fruit (Aventi, 2015). Based on the data from the ANOVA analysis results from three different altitudes, the results show that altitude does not have a significant effect on the water content of pineapples, this is presented in the table.

Table 2. Average water content of fruit at different altitudes.

Altitude (masl)	Water content %
Low (384)	87% a
Medium (643)	87% a
High (1019)	88% a

Note: The average values between treatments followed by the same letter were not significantly different based on the 5% LSD test.

Table 2 shows that the altitude does not have a significant effect on the water content of pineapple. This means that the water content of pineapple is relatively stable at various altitudes, but the highest percentage of water content is in the highlands with a value of 88%, and low and medium altitudes have the same water content value of 87%.

There are several environmental factors that may explain why pineapples at higher altitudes show higher water content, although the difference is not significant. At higher altitudes, air temperatures tend to be lower and relative humidity is higher. These conditions can reduce the rate of water transpiration from the fruit, resulting in higher water content in the fruit. And with lower transpiration rates, plants can retain more water in their tissues, which may contribute to the slightly higher water content in pineapples grown at higher altitudes.

Total dissolved solids (Brix˚)

Total dissolved solids is an indicator that is closely related to fruit quality. This dissolved density usually refers to the concentration of sugar contained in the fruit. Based on the data from the ANOVA analysis of three different altitudes, the results showed that altitude significantly affected the brix content of pineapple fruit. Then, the data was further processed using a 5% LSD follow-up test, and the results were obtained in Table 3.

Table 3. Average total dissolved solids at different altitudes.

Altitude (masl)	Total Dissolved Solids (Brix°)		
	D1	D4	D7
Low (384)	17.4 b	16.6 ab	16.9 b
Medium (643)	17.9 b	17.8 b	17.5 b
High (1019)	16.0 a	15.4 a	14.8 a

Note: The average values between treatments in the same column followed by the same letter were not significantly different based on the 5% LSD test.

Table 3 shows a significant difference in honey pineapple fruit in the highlands compared to honey pineapple fruit in the lowlands and medium. In the observation data on the first, fourth and seventh days, the highlands have the smallest average values of 16, 15.4 and 14.8 while in the lowlands and medium there is no significant difference but the largest brix value is found in the medium plain fruit with an average value of 17.9, 17.8 and 17.5 while the lowlands have an average value of 17.4, 16.6 and 16.9.

Brix level is a measure of the concentration of dissolved sugar in fruit, which is often used as an indicator of fruit sweetness. Research shows that there are differences in the brix levels of honey pineapple at different altitudes. The study results show that pineapples grown at medium altitudes had higher brix levels than fruit grown at higher and lower altitudes.

This phenomenon can be explained by several factors related to altitude. As in grapes, the sugar content is higher and tartaric acid is lower if the fruit is grown at high temperatures (Moretti et al., 2010). Honey pineapple fruit also has a high sugar content because the air temperature and light intensity tend to be high, which can increase the metabolic rate of plants, such as the process of photosynthesis. This increase in the photosynthesis process can produce more carbohydrates, which are then converted into sugar in the fruit. In addition, the height of the medium may also provide more optimal conditions for the accumulation of sugar in the fruit due to lower osmotic pressure and higher water evaporation, so that the sugar concentration in the fruit increases. However, if the temperature is too high it can also result in a lack of sugar content because respiration consumption is greater than the accumulation of photosynthesis, resulting in the depletion of carbohydrate reserves (Chang & Lin, 2020). As happens with honey pineapples in the lowlands.

On the other hand, at higher altitudes, lower temperatures and higher humidity can slow down the metabolic processes of plants. At high altitudes, atmospheric pressure conditions also become lower and can reduce the partial pressure of O2 and CO2, which are essential substrates for the respiration and photosynthesis processes (Arce et al., 2021). So that the raw materials needed by plants for metabolism such as photosynthesis cannot be met. This can cause lower sugar accumulation in pineapples, so that the brix levels produced are lower than those grown in medium and lowlands.

Vitamin C

Vitamin C or ascorbic acid is one of the vitamins that can dissolve in water. Vitamin C in liquid form is very easily oxidized to dehydroascorbic acid, which causes the levels of this vitamin to decrease quickly and be easily damaged (Sarni et al., 2020). Based on the data from the ANOVA analysis, the altitude of the place significantly affects the vitamin C content in pineapple. Then, the data was further processed using the 5% LSD follow-up test, and the results were obtained in the following table.

Table 4. Vitamin C levels of honey pineapple at different altitudes.

Altitude (masl)	Vitamin C		
	D1	D4	D7
Low (384)	21.702 a	17.494 a	16.280 a
Medium (643)	23.106 a	18.710 a	17.122 a
High (1019)	26.192 b	22.170 b	19.644 b

Note: The average values between treatments in the same column followed by the same letter were not significantly different based on the 5% LSD test.

Table 4 shows a significant difference in each treatment and observation period. At higher altitudes, there is a higher vitamin C content; on the observation period of day 1, the vitamin C content is 26.192, while at lower altitudes, the vitamin content is lower, namely 21.702. This aligns with the study's results (Fatchurrozak et al., 2013) where the highest vitamin C content in Carica Pusbecens fruit was found at 2400 meters above sea level. This finding is in line with the view that the altitude of the location affects the metabolic processes of plants, including biochemistry and synthesis of secondary metabolite compounds.

At higher altitudes, temperatures decrease, humidity increases, sunlight intensity decreases, and the duration of exposure becomes shorter, which causes plants to experience stress. When plants are under stress, the production of secondary metabolites, including

vitamin C, tends to increase in response to these environmental conditions. Vitamin C is easily oxidized because it is water-soluble, and this oxidation process converts it to dehydroascorbic acid.

Each plant has an optimum temperature that supports the metabolic process, including honey pineapple, which also has an ideal temperature for vitamin C metabolism. Based on research data, it can be concluded that the optimum temperature for vitamin C production in honey pineapple plants is at a higher altitude.

Anthocyanin

Anthocyanins are natural pigments that are soluble in water and belong to the flavonoid family. Anthocyanins play an important role in seed dispersal, pollination, plant organ development, and can compensate for biotic changes caused by pathogen attacks, and abiotically anthocyanins can adapt to drought, nutrient deficiencies, and high intensity light (Šamec et al., 2021). Based on the ANOVA analysis of three different altitudes, the results show that the altitude has a significant effect on the levels of pineapple anthocyanin. This is presented in table 5.

Table 5. Average anthocyanin content of honey pineapple skin at different altitudes.

Altitude (masl)	Anthocyanin content (g/ml)
Low (384)	0,01326 b
Medium (643)	0,01700 c
High (1019)	0,00966 a

Note: The average values between treatments followed by the same letter were not significantly different based on the 5% BNT test.

Table 5 shown that altitude has a significant effect on the anthocyanin content of pineapple fruit. This is because anthocyanin can be affected by various parameters such as relative humidity, light, pH, temperature, sugar, vitamin C, oxygen levels, sulfur dioxide, enzymes, co-pigments and metal ions (Sharma et al., 2016). So that the anthocyanin levels with higher amounts are found in medium plains with 0.017 g/ml at low altitudes with 0.01326 g/ml and in highlands there are results of 0.00966 g/ml lower than medium and low plains, this shows that the higher the surface of the place, the faster the rate of decline in anthocyanin content will be affected by high temperatures so that with increasing temperatures, degradation of the anthocyanin molecule compound can occur (Enaru et al., 2021). Light intensity is also the most important external factor that influences fruit color

so that the chlorophyll synthesis process upon exposure to light will influence the composition and content of carotenoids in plastids (Lu et al., 2024).

Fruit Shelf Life

Shelf life is one of the problems faced by many farmers and fruit and vegetable traders when developing and marketing their products, so information about the shelf life of the product is needed. So this is related to product safety and product quality, the shelf life of the fruit can be observed through the process of decay speed in the fruit area, the shelf life of pineapple is influenced by several factors including the level of ripeness, weight, water content and total dissolved solids (Khairi et al., 2017). Based on the ANOVA data from three different altitudes, this shows that altitude has a significant effect on the shelf life of pineapple. This is presented in table 6.

Table 6. Average shelf life of fruit at different altitudes.

Altitude (masl)	Shelf Life (Days)
Low (384)	15 b
Medium (643)	13 ab
High (1019)	11 a

Note: The average values between treatments followed by the same letter were not significantly different based on the 5% BNT test.

Table 6 shows a significant difference in honey pineapple fruit in the highlands compared to honey pineapple fruit in the medium and lowlands. In the highlands, honey pineapple fruit rots faster because the water content in pineapple fruit in the highlands is higher than in the medium plains, but pineapple fruit in the medium plains rots faster than in the lowlands. This shows that high temperatures can cause the transpiration process to be faster than low temperatures so that it can affect the freshness of honey pineapple fruit which is more prone to rot. The longer the storage, the more it can cause a decrease in the quality and quality of the fruit, which is caused by room temperature factors, high storage temperatures can cause the respiration rate to increase (Fertiasari et al., 2023).

CONCLUSION

The research results show that the height of the growing place significantly affects the quality of honey pineapple fruit, such as fruit weight, total dissolved solids, vitamin C, shelf life, and anthocyanin content. However, it does not have a significant effect on the

water content of the fruit. In the medium plains, the fruit weight value (566.64 g), total dissolved solids (17.9%), and anthocyanin content (0.01700 g/ml) are higher compared to the highlands and lowlands. While the vitamin C value (23.106) and water content (88%) are higher shown in the highlands with an altitude of 1019 meters above sea level.

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