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International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Index Copernicus Value (2015): 56.67 | Impact Factor (2017): 5.156

Nondestructive Prediction of Physical and Chemical Characteristics of Banana (*Musa paradisiaca* L.) Based on Color Change

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Abstract: ***The objective of the research was to predict the physical and chemical characteristics of banana (Musa paradisiaca* L.) *non destructively based on discoloration. The first stage of the research was to determine the most preferred physical and chemical characteristics of banana; and the second stage was to analyze the effect of the banana's maturity (A) and banana's natural ripening period (B) on the changes of physical and chemical characteristics of banana that was arranged in a factorial completely randomized design. The determined parameters were color analysis (L*, a*, b*), texture, pH, total sugars content, vitamin C, total acids content, the kinetics of color changes and hedonic test. Hedonic test showed that the most preferred banana was the perfect ripe banana with the characteristics of L* 63.23%, a*-1.63, and b* 33.27 on banana's peel, total sugars content of 9.4 ^{0}Brix, pH 5.007, texture (hardness) 35.78 gf, vitamin C content 4.69mg/100g, and total acid content 1.15%. Kinetic changes characteristics on the banana's peel based on the maturity level of bananas were k (rate of constant) values for L* were 4×10^{-3}, -2×10^{-4} and -3×10^{-4} per day, respectively for the bananas harvested at 60, 80 and 100 days after flowering, whereas the k values for b* were -4×10^{-4}, -1×10^{-3} and $2{,}6\times10^{-2}$ per day, respectively. The natural ripening period for bananas harvested at 60, 80 and 100 days after flowering that could meet the preferred b* values on banana's peel were 33.17; 9.46 and 7.18 days, respectively.***

Keywords: nondestructive, prediction, banana, color

1. Introduction

Fruit ripening is a complex process and it is a natural processed indicated by the changes of color, aroma, texture, and nutritional value. The changes are as a result of several genetic and biochemical pathways, which are influenced by internal and external factors and regulated by many factors [1].

Banana contains relatively high carbohydrates as an energy source, as well as a source of several vitamins, and minerals for supporting human health. Unripe banana contained starch in the ranges from 20% to 25% [2]. Some banana varieties have different characteristics of simple starch and sugar constituents. Banana changes in texture and color during ripening. Unripe bananas that are originally green and hard in texture will turn yellow and soften during the ripening phase [3].

The color and texture of the fruit are very important factors in evaluating the quality of food products. The value of *L* *, *a* * and *b* * would change and affect the total color appeared on outer of fruit. The color changes describe the level of maturity, and there is a linear correlation between discoloration and fruit texture [3]. Some studies of bananas have been carried out from cultivation to post-harvest [4][5][6], but not many studies have examined the correlation between the color changes of banana peel with the physical and chemical characteristics of banana meat, particularly banana *ambon* variety. Banana *ambon* is one of table fruit and consumed freshly. The demand of banana *ambon* is relatively high especially with optimal maturity, and it is hard to obtain banana *ambon* with the optimal ripe maturity in large quantity at the same time. Therefore, it is necessary to analyze the kinetic changes in the physical and chemical characteristics of banana *ambon* based on color changes during natural ripening.

The kinetic approach is based on the rate of process associated with the dependent and independent variables [7]. Dependent variables that influence ripening of bananas include temperature and time. Independent variables include starch, organic acid and ethylene content. The observed rate of parameter change is expressed in *k* (rate of constant) which is calculated based on the reaction order that occur during ripening. Degradation of starch during ripening process used to follow the first reaction order, while the formation of some simple sugars such as glucose and fructose follows a zeroth reaction order. The value of *k* is obtained by calculating the changes in product quality based on the function of time [8].

This study examined the physical and chemical characteristics of bananas *ambon* at various maturities which were associated with the rate of discoloration in natural ripening conditions at room temperature. The physical characteristics observed were color and texture, while the chemical characteristics observed were total and total acid content. Sensory analysis was carried out as a study of the first stage to determine the most preferred banana *ambon* based on the score of the taste, color and texture. The correlation between the rate of discoloration and physical and chemical characteristics would give a kinetic equation as a time function. The kinetic equation based on this time function is expected to be used to predict the physical and

chemical characteristics of bananas in a simple method according to the preference of consumers.

2. Materials and Method

2.1. Banana Preparation

All samples of bananas *ambon* were obtained from the same plantations. Those samples were selected and harvested based on the categories according to its maturity as follows: 1) 60 days after flowering (denoted as A1), 2) 80 days after flowering (A2), and 3) 100 days after flowering (A3). The harvested bananas were cleaned from dust and dirt by using a dry brush. Bananas were placed in a basket and then brought into the laboratory the natural ripening process and analysis. Those samples were placed in a room at the temperature of (29±1) ^{o}C for the natural ripening process for 0 (B1), 3 (B2), 6 (B3) and 9 (B4) day(s).

2.2. Changes in the physical and chemical characteristics of banana ambon during ripening

The data collected for color measurement (L *, a *, b *) was analyzed by ANOVA. If the results of ANOVA analysis showed a significant effect, then they were further analyzed by Tukey's test. The kinetics of discoloration in the peel of bananas *ambon* during ripening was analyzed by using *Arrhenius* equation.

2.3 Physical and chemical analysis

Physical analysis included color analysis (L *, a *, b *, and ΔE *) (CR-10 plus Konica Minolta color reader) and texture analysis (texture analyzer with TA 39 cylinder probes, LFRA 1500, Brookfield, USA' texture analyzer). Chemical analysis included analysis of total sugar content (refractometer), analysis of vitamin C (iodine titration method), pH (pH meter) and titrated total acid analysis (titration method).

3. Results and Discussion

3.1 Criteria for the preferred banana *ambon*

Analysis of the criteria of the preferred banana *ambon* was based on hedonic tests. The hedonic test showed that the most preferred banana *ambon* was banana that was in perfect level of maturity with the physical and chemical characteristics as follows: lightness 63.23%, a * -1.63, and b * 33.27 on the peel of banana *ambon*. total sugar content 9.4^{o}Brix, pH 5.007, texture 35.78 gf, vitamin C 4.69 mg/100 g, and total acid 1.15%

3.2 Effect of maturity and ripening period on the physical properties of banana *ambon*

3.2.1 Color Analysis

Color changes on banana peels were due to chlorophyll degradation and carotenoid synthesis during ripening. The color of the banana peel would change in the values of L*, a*, b*, and ΔE * [3]. During ripening at room temperature (29^{o}C), the lightness of the banana peel increased until the sixth day of ripening period. After that the value of lightness decreases due to the accumulation of the formation of phytol compounds from the degradation of chlorophyll by chlorophyllase enzyme and carotenoid synthesis by *phyteine syntase*. Color changes during ripening from green to yellow are associated with increasing values of a*, b*, and hue [9]. The lightness of banana peel increased until day six of ripening period, then decreased with the maturity or ripening period [10].

The decrease in the lightness of the banana *ambon* after the sixth day of ripening period was due to some enzyme activities had been in the maximal enzyme activities phase. After six days of ripening, there was an accumulation of compounds resulting from chlorophyll degradation and carotenoid synthesis. Fruits that have not been picked, chlorophyll will be available maximally until the mature phase. In this condition, the activity of the enzyme chlorophyllase might reach its peak to breakdown chlorophyll that is indicated by the changes of green to yellow on banana peel. Chlorophyllase enzyme that was located inside chloroplast would breakdown chlorophyll into phytol which was responsible for decreasing values of L *, a *, and b * [10].

Banana is categorized as a climacteric fruit that is indicated by the occurrence of a series of metabolic processes such as respiration. Ethylene will stimulate the activity of maturing enzymes, mainly due to the effect of temperature changes, as well as bruises on the peel. The green surface on the banana *ambon* peel might turn into yellowish green as a result of a transition from the function of chloroplasts into chromoplast containing carotenoid pigments [11]. The carotenoid pigments found in the banana *ambon* are responsible for the increase in the value of a * and b * on the banana *ambon* peel. During ripening, chlorophyll was broken down by the chlorophyllase enzyme which caused green on the banana peel turn into yellow followed by carotenoid synthesis by the enzyme *phyteine syntase* which was characterized by a decrease of a* value and an increase of b* values [12].

3.2.2. Total color difference (ΔE *)

The total color differences analysis (ΔE *) was carried out by subtracting the color values of the most preferred banana *ambon* (as a standard) to the color values of the selected sample. The most preferred banana *ambon* (as a standard) had the physical and chemical characteristics as follows, lightness 63.23%, a * -1.63%, and b * 33.27% on banana *ambon* peel, total sugar content of 9.4 ^{o}Brix, pH 5.01, texture 35.78 gf, vitamin C 4.69 mg/100g, and total acid 1.15%. The calculation of ΔE * is presented in Table 3.1.

Table 3.1: Total color differences (ΔE *) analysis

Treatments	ΔE^{*}
A1B1	14.17
A1B2	12.20
A1B3	11.70
A1B4	10.03
A2B1	11.41
A2B2	9.66
A2B3	7.33
A2B4	6.38

A3B1	14.24
A3B2	11.94
A3B3	6.72
A3B4	5.11

The data in Table 3.1 shows the lowest value of ΔE *found in A3B4 treatment (100 days after flowering and 9 days of natural ripening). Comparison of the physical and chemical characteristics of the most preferred (standard) banana *ambon* and the treatment of A3B4 is presented in Table 3.2.

Table 3.2: Comparison of the physical and chemical characteristics of the most preferred banana *ambon* and the treatment of A3B4

Properties	Banana *ambon* (Standard)	A3B4
Lightness (%)	63.23	59.19
a^* (%)	-1.63	-3.11
b^* (%)	33.27	30.11
Texture (gf)	35.778	61.36
Total sugar content (°Brix)	9.4	5.07
Vitamin C (mg/100g)	4.69	5.87
Total acid (%)	1.15	0.99
pH	5.01	5.01

The data in Table 3.2.4.2 shows that the total sugar content of A3B4 is 5.07°Brix and 9.4°Brix for the standard banana *ambon*. There is a difference between the total sugar content in the standard banana and the treatment of A3B4. It was due to the standard banana obtained from the market has been treated with ethylene induction with the addition of carbide during ripening by the traders. The addition of ethylene for induction such as carbide in the ripening process will trigger ethylene activity. Therefore, production and enzyme maturation activities run faster than normal conditions. This would have an impact on hydrolysis of starch and other complex carbohydrate compounds in the standard bananas into simple carbohydrates such as glucose [13].

3.3. Kinetics analysis of the lightness (*L**) on banana peel during ripening

Kinetic analysis of color changes (lightness, a *, b *) of the banana peel during ripening is based on by Arrhenius equation. The kinetic analysis of changes in the lightness of banana peels is presented in Table 3.3.

Table 3.3: Kinetic changes of *L** on the banana peel

Maturity (days)	Kinetic eq.	R^2	Reaction order	*k*
60	y = 0.004x + 1.74	0.99	1	0.009
80	y = -0.0002x + 0.018	0.80	2	-0.0002
100	y = -0.0003x + 0.018	0.80	2	-0.0003

Table 3.4: Rate of constant (*k*) and predicted ripening time (t) based on *L** changes

Maturity (days)	*k* (per day)	*t* (days)
60	0.004	14.78 days
80	-0.0002	8.36 days
100	-0.0003	6.31 days

Banana *ambon* at the harvesting period of 60 days after flowering took a longer ripening period (14.45 days) than other treatments, the harvesting period of 80 days after flowering took 8.36 days and 100 days of harvesting period was 6.31 days to achieve the consumers' preference properties of banana *ambon*. During ripening of banana *ambon* which was originally dark green on its peel would change into light green.

3.4. Kinetics analysis of the yellowness (*b**) on banana peel during ripening

Table 3.5: Kinetic changes of *L** on the banana peel

Maturity (days)	Kinetic eq.	R^2	Reaction order	*k*
60	y = -0.0004x + 0,044	0.693	2	-0.0004
80	y = -0.001x + 0,04	0.938	2	-0.001
100	y = 0.026x + 1,354	0.932	1	0.061

Table 3.6: Rate of constant (*k*) and predicted ripening time (t) based on *b** changes

Maturity (days)	*k* (per day)	*t* (days)
60	-0,0004	33,17
80	-0,001	9,46
100	0,026	7,18

There was an increase in yellowness (b*) on the banana *ambon* during ripening which was indicated by the increase of *b** value. The banana peel which was originally green turning to light yellow, bright yellow and finally to light brown.

4. Conclusion

Banana that was harvested after 100 days after flowering took approximately 6 days of natural ripening to meet the preferred characteristics for most consumers, whereas harvested after 80 days and 60 days took approximately 14 and 8 days of ripening period.

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