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Research Article

Effect of Artificial Ripening Techniques on Physico-Chemical Properties of Banana (*Musa* sp) Variety 'Poovan'

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ABSTRACT

In recent days, artificial ripening techniques for fruits are widely used worldwide due to commercial value and consumer acceptability of attractive fruit colour. Banana (Musa sp) variety 'Poovan' fruits were dip treated with different artificial ripening agents such as ethephon and calcium carbide. The study was carried out at ambient temperature to induce the ripening process. Different physico-chemical parameters such as titrable acidity, pulp to peel ratio, TSS, and texture were measured for all these banana samples. The colour values, TSS, pulp to peel ratio increases; and titrable acidity and firmness (penetration force) decreases with increase in ripening time. The calcium carbide treated banana found to be with lowest firmness (1.51 kg/s). The colour values increased drastically in artificially ripened banana samples. Naturally ripened banana showed lowest titrable acidity (0.09%). Pulp to peel ratio was found higher (2.30) in naturally ripened banana. Artificially treated banana was highly acceptable than naturally ripened banana in sensory evaluation.

Key words: *Artificial ripening, Calcium carbide, Ethephon, Physicochemical properties, Ripening agents, Poovan banana*

INTRODUCTION

Banana is considered as a highly consumed and locally available fruit; total worldwide banana export for the year 2018 was found to be 19.2 million tons[8]. The poovan variety banana fruit is slightly acidic firm and has typical sour-sweet aroma. Poovan variety is cultivated throughout the country but mainly cultivated in Tamil Nadu owing to its climatic and marginal soil conditions. Banana fruit contains easily digestible carbohydrates, minerals and vitamin C[19]. Fruits undergo many chemical and physical changes and gradually become soft, coloured, palatable and sweet, the process is known as fruit ripening[29,4]. The various kinds of artificial ripening process have been established to complete the high consumer demand with the development of science and technology. The artificial fruit ripening is a matter of worry because of its wellbeing related issues as of late[9,32,18].

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The combination of molecular, biochemical and physiological processes results in the natural fruit ripening process[4,20]. The different metabolic process combinations such as softening of fruit, increase in sugar content, responsible for changes in color due to deactivation and activation of various genes, increase in aroma and flavor, decrease in acidity includes in fruit ripening process[6,33]. Different chemical agents help in initiating the artificial ripening process[13,32]. The chemical agents such as jasmonate, methanol, ethanol, calcium carbide, ethephon, and ethylene glycol are used for artificial fruit and vegetable ripening as described by various research groups[32].

Ripening agents are reported with different types of impurities[9,32]. Also ripening agents have caused a concern in health as they have resulted in considerable health issues. Ethephon encompasses impurities like monochloroethyl ester of (2-chloroethyl)-phosphonic acid and 1,2-ethanediylbis (phosphonic acid) and[31,7]. Then it destroys monochloroacetic acid[7]. The symptoms such as fatal systematic poisoning and burn injury shown when skin comes in contact with monochloroacetic acid[27]. Acetylene gas produced as a by-product of the calcium carbide and water reaction, also acts like natural ripening hormone that is ethylene gas[9]. Phosphorous hydride and arsenic can be found in the mechanical evaluation of calcium carbide[32]. Calcium carbide could come in direct contact with laborers while applying it on fruits. More contact with phosphorus and arsenic can cause a development of liquids in lungs with primary symptoms of burning sensation in the abdomen and chest, vomiting, diarrhoea, weakness, thirst, irritation or burning in the skin and eyes, difficulty in swallowing, sore throat, permanent eye damage, shortness of breath and cough, ulcer on the skin[32].

The study of different research groups has described that direct consumption or direct exposure of artificial ripening agents caused possible health hazards[11,32]. Like antacid nature of calcium carbide bothers the mucosal tissues of the stomach area. A few cases have been accounted for about the stomach issue in the wake of eating carbide-ripened mangoes[32]. Kidney failure can be caused due to generous consumption of ethylene glycol[11]. Some chemicals are stated to be safe for human consumptions such as methyl jasmonate and ethylene but are not widely used due to relatively expensive nature[30]. The chemicals such as ethylene glycol, calcium carbide, and ethephon are low-cost chemicals preferred in many different countries[17].

Hence, the qualification and quantification of changes in the physicochemical properties of artificially ripened banana fruits are important to study with effective scientific investigation and additionally to assess any probable wellbeing risk related with the ingestion of these fruit products. The present research focused on the development of the scientific consideration to find the changes in physicochemical characteristics of artificially ripened fruits.

MATERIAL AND METHODS

Raw Material Procurement

The Poovan banana variety was procured from the Thanjavur District local market. Completely unripened bananas were used for the trials, so the raw materials were procured frequently on the basis of requirement. The ripening of banana fruits has been carried out at ambient temperature in the lab scale ripening setup following commercial ripening practices. The experiment was carried out with the application of different ripening agents such as ethephon and calcium carbide with natural ripening process and ripening study was conducted.

Artificial ripening agent treatments

Ethephon treatment

Ethephon treatment was given to the unripe banana with the ethephon solution of 50 ml (300 ppm). The enclosed condition of treated banana samples was continued for 24 hours and accessible to the atmosphere[24].

Calcium carbide treatment

Calcium carbide powder (2g) was packed in thin layer paper and then kept in the container

(1.5L) with the fresh unripe banana sample. The calcium carbide packet was dipped in water before placing in the container. The ripening of treated banana carried out in enclosed conditions[24].

Experimental techniques

The method for determination of titrable acidity, pulp to peel ratio, TSS, color and texture of banana samples are discussed in the following sections.

Titrable acidity

Titrable acidity (TA) is the number of protons recovered during titration with a strong base to a definite endpoint. It was determined by the method given by the standard A.O.A.C[1]. For the analysis, 10 g of pulp was taken in a beaker and mixed with 40 g of distilled water. Then 10 ml of liquid was taken from the solution in a volumetric flask and included with 2-3 drops of phenolphthalein indicator pursued by titration against 0.1 N NaOH arrangement and burette reading was noted down. TA is expressed based on % malic destructive present in banana. Using the following formula, titrable acidity was determined.

$$\% \text{ acid} = \frac{[ml\ of\ NaOH\ used]\times[0.1N\ NaOH]\times[milliequivalent\ factor]\times 100}{grams\ of\ sample}$$

For banana, milli equivalent factor is taken as 0.067. Titrable acidity was determined during each day of storage or ripening of red banana[1].

Total soluble solid

The lab level refractometer was used to determine total soluble solids (Make: ATAGO, RX-7000, Japan) (Plate 3.12), as described by Soltani *et al.*[34]. A drop of banana pulp was squeezed out onto the refractometer and reading was taken as total soluble solids. TSS value is expressed in terms of °Brix. A refractometer is based on the principle of increase in density of substance also increases its refractive. Refractive index (nD) varies in the range 1.32422 to 1.70000. Brix varies in the range of 0.00 to 100.00% (Automatic Temperature Compensation).

Pulp to peel ratio

The division of weight of pulp to the weight of peel results in the pulp to peel ratio. Unripe banana can be peeled by using sharp edge knife. Then both pulp and peel were separated and individual weights were taken using a digital weight balance[26]. Pulp to peel ratio is determined by using the formula given below.

$$\text{Pulp to peel ratio} = \frac{Weight\ of\ pulp}{Weight\ of\ peel}$$

Color

Hunter color lab flex meter (Make: Hunter Association Laboratory, Inc., USA) was used for the determination of the color of banana peel. The working principle includes focusing of light with measurement of the reflected energy of the sample around the entire visible spectrum. The color is estimated as far as 'L', 'a' and 'b' in which vertical axis formed by lightness (L) forms, which indicates whiteness to darkness. The a (+) redness, a (-) greenness, b (+) yellowness, and b (-) blueness indicates the chromatic portion of solids[15]. The ΔE values of all the samples calculated using the following formula.

$$\Delta E = [(L_2\text{-}L_1)^2 + (a_2\text{-}a_1)^2 + (b_2\text{-}b_1)^2]^{1/2}$$

Textural analysis

The texture analyzer was used to measure texture parameter of red banana viz. firmness (Model TA- XT, Stable Micro System Ltd, UK). The EXPONANT software program was used to record the data loaded in the linked computer.

The firmness of the fruits and vegetables was carried out by puncturing the sample that generated a force vs. time graph. The measurement of firmness value was done with the working conditions such as mode-measure force in compression, pre-test speed 1.5 mm/s, test speed 1.0 mm/s, post-test speed 10 mm/s trigger type-auto 5 kg, the data acquisition rate, and accessory were 5 mm

cylinder probe (P/5) and heavy-duty platform (HDP/90). The banana is kept on a heavy-duty platform of the analyzer with the steadiest position, triplicate readings were taken at three different points of fruit and recorded[23].

Sensory quality characteristics:

Descriptive sensory quality of ripe banana fruits viz, texture, aroma, colour, appearance, flavor, mouth feel, taste and overall quality were assessed by a panel of 10 judges.

Statistical Analysis:

All the experimental values analyzed statistically as analysis of variance (ANOVA) by using SPSS software (IBM SPSS Statistics V20.0.0, USA) at 95% confidence level. The data were analyzed at a probability level ($p<0.05$).

RESULTS AND DISCUSSION

The changes in physical and chemical characteristics of banana var 'Poovan' shown in table 1 and table 2 respectively.

Titrable acidity

The initial titrable acidity was found to be 0.18% (raw banana-control. The titrable acidity decrease with increase in the storage time or ripening time in all the samples. The titrable acidity recorded at 72 h was 0.09%, 0.11%, 0.12% and 0.10% in naturally ripened banana, banana treated with ethephon, banana treated with calcium carbide and banana samples from local market respectively. Higher reduction of titrable acidity was found in the naturally ripened banana sample as compared to artificially ripened banana samples. The control sample showed an expressively higher value with respect to artificially and naturally ripened banana sample. Similar observations were made by Md. Nazibul Islam *et al*.[24], & Ho *et al*.[14],

Total soluble solids (TSS)

The TSS values were found to increase with storage time. The initial TSS value was 8.78 ˚Brix. The TSS recorded on 72 h storage time was 19.04, 19.16, 17.15 and 20.01˚Brix in naturally ripened banana, banana treated with ethephon, banana treated with calcium carbide and banana samples from local market, respectively. In artificial ripening, calcium carbide treated banana sample have lower TSS as compared to other ripened samples. The lowest TSS was recorded in calcium carbide treated banana. The banana samples from local market found to be higher TSS sample. The reaction of the breakdown of starch into soluble sugars responsible for the increase in the TSS values. Chemical ripening agents increase the rate of starch breakdown, thus gives higher TSS values than the natural banana sample. The results for naturally ripened banana was comparatively similar to the reported literature by Kulkarni *et al*.[21],

Pulp to peel ratio

Naturally ripened banana sample shown higher pulp to peel ratio among the ripened samples. The pulp to peel ratio of raw banana was 1.58. Pulp to peel ratio increases with storage time. The pulp to peel ratio recorded at 72 h, was 2.30, 2.16, 2.18 and 2.00 in naturally ripened banana, banana treated with ethephon, banana treated with calcium carbide and banana samples from local market, respectively. The use of chemical ripening agents increases the respiration rate of fruits. Thus, the chemical metabolism process speeds up and results in the increased pulp to peel ratio of artificially ripe banana fruit. Similar experimental values for naturally ripened banana were found in the literature by Kulkarni *et al*.[21],

Color

The color values change as banana changes its ripening stage. The green color is shown by the unripe banana and fully ripe banana is yellow in color with brown color spots. There is a significant change in L* value of banana in which naturally ripened banana shows highest L* value. Ethephon treated banana shows highest a* value and banana collected from local market shows lowest a* value as compare to control sample. Highest b* value was found in naturally ripened banana and lowest in calcium-treated banana samples. After complete ripening, artificially ripened banana samples shown more ΔE value as compare to naturally ripened banana samples. In artificially ripened banana samples, ΔE value was highest for ethephon treated banana sample followed by calcium treated banana

samples. The observed values were found similar to the literature published by Gandhi *et al*[10].

Texture

The firmness value recorded by texture analyzer in kg per unit force. The firmness decreases with storage time. In artificially ripened samples, calcium carbide treated banana sample have the lowest firmness value after 72 hours. The rate of change of fruit firmness is higher in the treated banana as compare to natural banana samples. The changes in the fruit firmness could be due to the production of soluble pectin by the breakdown of insoluble protopectin followed by cellular breakdown results in the membrane permeability. In the case of the artificial ripening, chemical ripening agents trigger the cellular fragmentation of the insoluble protopectin and result in a gradual decrease in fruit firmness. The experimental results were similar to the reported literature Gandhi S. *et al*[10].

Sensory evaluation

The calcium carbide treated banana sample found highly acceptable in sensory evaluation. The sensory evaluation revealed that the artificial ripening agents helps in increasing the consumer acceptability of banana fruit. The naturally ripened banana sample showed lowest acceptability in comparison to artificially ripened banana. The results of sensory evaluation are shown in Table 3. The estimated values were found similar with literature Gunasekara *et al*[12].

Table 1: Changes in physical properties of banana (var 'Poovan') during ripening

Storage time (h)	Treatments			
	Naturally ripened banana	Banana treated with ethephon	Banana treated with calcium carbide	Banana collected from local market
Pulp/peel ratio (1.58)				
24	1.59^{aA}	1.69^{aB}	1.72^{aC}	1.73^{aD}
48	2.15^{bA}	1.75^{bB}	1.78^{bC}	1.60^{bD}
72	2.30^{cA}	2.16^{cB}	2.18^{cC}	2.00^{cD}
L* (52.28)				
24	49.63^{aA}	55.64^{aB}	49.85^{a}	52.96^{a}
48	49.47^{A}	56.07^{B}	56.47	53.26
72	56.05^{cA}	55.67^{cB}	55.51^{c}	54.56^{c}
a* (-8.19)				
24	-2.87^{aA}	-0.67^{aB}	-4.81^{a}	-2.35^{aD}
48	0.69^{bA}	6.6^{bB}	4.75^{b}	2.76^{bD}
72	5.06^{cA}	8.44^{cB}	8.16^{c}	4.31^{cD}
b* (35.28)				
24	33.69^{a}	39.39^{a}	36.43^{a}	36.67^{b}
48	34.98	36.63	40.99	37.24
72	39.96^{c}	39.17^{c}	35.84^{c}	38.96^{c}
ΔE				
24	62.1^{aA}	72.23^{aB}	49.85^{aC}	36.68^{aD}
48	118.32^{bA}	222.48^{bB}	207.04^{bC}	124.72^{bD}
72	213.25^{cA}	296.10^{cB}	271.81^{cC}	172.07^{cD}
Firmness (5.84)				
24	5.28^{aA}	3.84^{aB}	3.87^{aC}	4.03^{aD}
48	4.74^{bA}	3.45^{bB}	3.7^{bC}	3.72^{bD}
72	2.71^{cA}	2.05^{cB}	1.51^{cC}	3.21^{cD}

*a,b,c are indicating significant difference between storage time and capital A,B,C,D are indicating significant difference between treatments at $p<0.05$

Table 2: Changes in chemical properties of banana (var 'Poovan') during ripening

Storage time (h)	Treatments			
	Naturally ripened banana	Banana treated with ethephon	Banana treated with calcium carbide	Banana collected from local market
Titrable acidity (0.18)				
24	0.16	0.15	0.15	0.16
48	0.12	0.14	0.13	0.13
72	0.09	0.11	0.12	0.10
TSS (8.78)				
24	10.35^{aA}	11.21^{aB}	11.57^{aC}	11.21^{aD}
48	15.78^{bA}	16.38^{bB}	16.84^{bC}	16.27^{bD}
72	19.04^{cA}	19.16^{cB}	17.15^{cC}	20.01^{cD}

**a,b,c are indicating significant difference between storage time and capital A,B,C,D are indicating significant difference between treatments at p<0.05*

Table 3: Sensory properties of banana (var 'Poovan') after ripening

Treatments	Appearance	Taste	Aroma	Texture	Mouthfeel	Acceptability
Control	4.19[a]	3.62[a]	2.14[a]	3.32[a]	2.08[a]	3.74[a]
Naturally ripened banana	5.34[b]	6.79[b]	5.46[b]	5.61[b]	5.77[b]	5.62[b]
Banana treated with ethephon	6.41[c]	5.40[c]	6.49[c]	6.03[c]	5.13[c]	6.36[c]
Banana treated with calcium carbide	6.73[d]	5.43[d]	6.81[d]	6.35[d]	5.41[d]	6.84[d]
Banana collected from local market	6.25[e]	5.72[e]	6.02[e]	5.82[e]	5.38[e]	5.92[e]

**a,b,c are indicating significant difference between treatments at p<0.05*

CONCLUSION

In recent days, artificial ripening agents are used worldwide due to economic reasons. Therefore, it is necessary to carry out the scientific research for the fundamental analysis of the ripening of fruits and fruits products, and point out the changes occur in the artificially ripened fruits and its health effects. The analysis of artificially ripened fruits, physicochemical properties and health effects of the adulterated food is an energetic process. In the present study, the physicochemical properties of the artificially and naturally ripened fruits are assessed and compared. Titrable acidity, total soluble solids, and pulp to peel ratio shown significant changes in artificially and naturally ripened banana samples. The titrable acidity of chemically ripened banana was higher than the naturally ripened banana. Total soluble solids were found higher in the banana samples from the local market. Naturally ripened banana sample show more amount of pulp to peel ratio as compared to artificially ripened banana sample. The color of banana changed according to the standard color chart. Artificially ripened banana sample found with more brightness and yellowness and increased value of ΔE. The firmness value (penetration force) was more for the naturally ripened banana. In artificially ripened banana samples, calcium carbide treated banana sample shown lowest firmness value. The presence of artificial ripening agents can be detected by various methods. the understanding, this examination will be useful for researchers, farmers, consumers, professionals, other stakeholders and legal authorities working for food safety because artificial fruit ripening creates complex issue due to its socioeconomic and health-related aspects.

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